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REPORT

ON THE

IRRAWADDY RIVER

PART IV

The Hydraulic Works

CONNECTED WITH

The Nawoon River

WITH APPENDICES

BY

R. GORDON, ESQUIRE, M. I. C. E., AND M. I. M. E

RANGOON.

PRINTED AT THE P. W. SECRETARIAT PRESS.

1880.

REPORT

ON THE

IRRAWADDY RIVER

PART I

Hydrography of the Irrawaddy River.

PART II

Hydrology of the Irrawaddy River

WITH APPENDICES

AND

SUPPLEMENTS A. B. & C.

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BY

R. GORDON, ESQUIRE, M. I. C. E. & M. I. M. E.

Executive Engineer, Henzada Division.

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RANGOON.
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1879.

BOMBAY BRANCH
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Royal Asiatic Society.
CLASS 12/2/11

ERRATA.

PART I.

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PART I.

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PART I.

The Hydrography of the Irrawaddy River.

INTRODUCTION.

1. It is necessary in investigating the causes of the Floods of the Irrawaddy to form a distinct conception of the extent and the peculiar conditions of its valley. These are, unfortunately, a matter of doubt, and any attempt to resolve this must be accompanied by a statement of the evidence bearing on the subject.

An examination of all the evidence at present available leads to the following conclusions:—1st. That the Irrawaddy is continuous with the Sanpo of Thibet; 2nd. That it receives the drainage of no other great river of Thibet; and 3rd. That the Sanpo is not connected with any other great river than the Irrawaddy, flowing to the sea. These conclusions are identical with those held by the great Geographer D'Anville, whose maps are still the principal authorities for the Thibetan Plateau. But as his views have either been ignored or rejected by many modern geographers, it appears indispensable to examine his claims to rank as an authority on the matter, as well as to examine the later information which has influenced views adverse to his. This information is, in any case, of importance in studying the Irrawaddy. A considerable amount of technical information can now be given concerning the floods as they appear in the delta, both as to their amount and mode of occurrence; and this, combined with such scattered knowledge as we possess of the floods in the higher parts of the river, affords the principal clue in tracing a solution of the problems.

SECTION I.

General examination of the features of the Irrawaddy.

The Delta of the Irrawaddy.

2. The discharge of the Irrawaddy was measured throughout an entire year from July 1872 to September 1873, at Saiktha, the head of the delta. At this point the river is confined to one channel, and has received, with a small exception, the whole of the waters drained into it. The measuring station is so fixed as to be above the highest point where the water can leave the channel to find its way by independent courses to the sea. A very few miles below Saiktha the flood waters spill over the left bank, or pass through it by creeks to the Hline and are carried past Rangoon to the sea without returning to the Irrawaddy. A few years ago they did the same on the right bank near Myanoung ; but the embankment works now in existence have stopped this. The water thus lost to the Irrawaddy on the right passed to the Nawoon River, which flows by Bassein to the sea. The Rangoon and Bassein Rivers are the extreme Eastern and Western mouths of the Irrawaddy. A direct distance of 140 miles, and a coast line of 160, intervene between these rivers ; while some other principal mouths debouch at irregular intervals.

Measurements of the discharge of the River.

3. Check measurements were made simultaneously with the above at Zaloon, 100 miles lower down on the main channel, and separately upon the Nawoon, just below where its two branches from the Irrawaddy unite. Further measments were made in the great flood of 1875. From all these, scales of discharges have been constructed, and the whole amount of water which has passed the head of the delta from 1869 to 1877, has been approximately calculated. The complete figures are given in Appendix I; and diagrams have been contructed (Plate V.) showing the results graphically. These will be dealt with in detail later on in the Report, but the principal facts may be noticed here. The total quantity of water discharged in the eight years 1870-77 was nearly 3,422,450 millions of metre-tons. (1.) The average is about 428 billion tons yearly. In the flood years 1871, 1875 and 1877 the discharges were about 482,465, and 466 billion tons. The least discharges recorded were in the years 1873 and 1876, when on each occasion 382 billion tons passed down to the sea.

Proportion of discharge.

4. The year is distinctly divided into two periods, the wet and the dry, 87½ per cent. of the total discharge passing in the six months, June to November, and 12½ in the other six. The proportion of the monthly discharges for the years 1870-77 is given approximately in Table I.

Table 1.

Jany.	Feb.	March.	April.	May.	June.	July.	Aug.	Sepr.	Octr.	Novr.	Decr.	Total.
2	1¼	1¼	2	3	7½	19	22½	18	14½	6	3	100

From this it is seen that August has the highest average, the quantity being 95 billion tons; the least is in February and March with averages of 5½ billion tons. The variation from the least monthly discharge to the highest is thus over

(1.) A cubic metre of water weighs very nearly one ton (55-56 ths.). This furnishes a convenient unit for comparison between English and Continental measures.

17 times. A marked regularity is observable in the ratios of discharge from year to year. Low water period extends from January to May. The latter part of that month or the beginning of June usually witnesses the rise of the river to mean flood. In ordinary years the river does not rise above mean flood, defining this by its continuing within its banks, when its discharge at Saiktha does not exceed 1,200,000 cubic feet per second, or about 3,000,000,000 tons per day. The period of mean flood may last from June to October. In years of high flood as well as in most ordinary years, the highest rise occurs in August. High flood is the stage beyond mean flood, where the river spills over its banks in the delta. This only happens in July, August or September. In October the fall commences, and is continuous through November and December sometimes reaching into January.

Comparison of discharge with other rivers.

5. The smallest discharge actually measured at Saiktha was 79,000 cubic feet per second on 3rd March 1873; but in 1877 the river was lower throughout than ever before known, and it was computed that only 46,000 cubic feet per second passed down on the 5th March. This was followed in the same year by the greatest flood ever known on the river, when on August the 20th, almost 5,000 million tons, or over 2,000,000 cubic feet per second, were discharged. At Thayetmyo 100 miles higher up this rate was exceeded. These figures convey no clear ideas by themselves. A few comparisons may aid a little. The Thames (1), discharged in the whole of one of the greatest flood years known, that of 1860, about 2,000 million tons at Lambeth. The Seine (2), at Paris, during one of the greatest floods of the century, discharged in the 54 days from 15th February to 10th April 1876, less than 4,500 million tons. Very few of the largest rivers of the world have been accurately measured, and the estimates usually given of their discharges are sometimes purely conjectural. Thus the Amazon's greatest flood discharge is variously given as over 8,000,000 cubic feet per second(3) and as 3,000,000 (4). The Congo is assumed to discharge over 2,000,000 cubic feet per second in flood (5). It is not much better when the older formulæ for discharge have been used, as these may err in giving $\frac{1}{3}$ the true result or three times the amount (6). Even the best estimates when not checked by measurements at the time are not quite trustworthy. The Mekhong (7) is given as with a flood discharge of over 2,000,000 cubic feet per second; but this appears too large from the data furnished. More accurate results have been obtained on the Po whose flood discharge is over 200,000 cubic feet per second; on the Danube, which near its mouth reaches 1,000,000; while the Ganges at Rajmahal has had 1,350,000 cubic feet; and the Jumna at Allahabad 1,330,000 cubic feet per second.

Comparison of discharge with that of the Mississippi.

6. A full comparison can only be made when the measurements have been prolonged over a considerable time and in varying conditions. This has been done for the Mississippi, the first great river on which a systematic investigation of flood discharge at different points, and of the whole of its hydrological conditions, has been thoroughly carried out. The operations conducted on that river have formed the model on which those applied to the Irrawaddy have been founded. The methods pursued are much the same, and the results are directly comparable. The comprehensive monograph of the Mississippi by Genrals Humphreys and Abbot (8) is worthy of the river, and furnishes the results of that investigation. These show that the greatest flood discharge ever known

(1). Sixth Report Parliamentary Commission for preventing the Pollution of Rivers 1874.
(2). { Belgrand Annales des Ponts et Chausees 1877.
Minutes of proceedings of the Institution of Civil Engineers Vol. I (1877).
(3). Reclus E La Terre, Vol I, P. 514 (1877).
(4). Lombardini E Guida dell' Idrologial P. 71 (1870)
(5). Stanley H. Letters to the Daily Telegraph (1877).
(6). Kutter W. R. Die neuen Formeln für die Bewegung des Wassers 1873 and 1877.
(7). Garnier F. Voyage d' Exploration in Indo-Chine (1873).
(8). Humphreys and Abbot. Report on the Mississippi 1861 and 1877.

upon the Mississippi was at Cairo in 1858, when it was 1,478,000 cubic feet per second, or about $\frac{2}{3}$ of that of the Irrawaddy at Saiktha in 1877. The smallest discharge never falls so low as on the Irrawaddy; being, in round numbers, 125,000 against 50,000 cubic feet The proportions between extreme flood and dry weather discharges are thus about 12 to 1 and 40 to 1 respectively. The average discharge of the Mississippi for the 43 years 1818 to 1860 was 19,400 billions of cubic feet per annum or nearly 550 billion tons; more than $\frac{1}{4}$ greater than that of the Irrawaddy. The modulus, or mean discharge per second for a series of years, is, for the Mississippi, almost 600,000 cubic feet, for the Irrawaddy 475,000 cubic feet. The variations of discharge from year to year are wider on the Mississippi than on the Irrawaddy; the greatest known on the former river being 830 billion tons, the least 314 billions; while for the latter the corresponding figures are 482 and 382 billions of tons. The wider range in the differences of the annual discharges on the Mississippi indicates a less uniform set of meteorological conditions than is found in the more tropical situation of the Irrawaddy; but the greater extremes of flood discharge and of low water discharge prove this last to undergo more widely diversified conditions of dryness and moisture within each year.

Drainage areas of the Irrawaddy and Mississppi Rivers.

7. When we consider the discharges with reference to the drainage areas, it is necessary to note that the rainfalls over the Mississippi Basin are more equally divided from season to season in each year. Probably the Summer rain is the heaviest over the greater portion of the area; but the evaporation will also be greater and the floods may come down in any season. The distribution of the discharges thus varies widely from that of the Irrawaddy. Here the rainy season lasts only six months, and this period of time alone can be taken in the comparison between the two rivers. The average semestrial discharge of the Mississippi is 275 billion tons; that of the Irrawaddy for the half year, June to November, about 375 billions. The ratio is nearly 3 to 4. The geography of the entire Mississippi Valley is pretty accurately known and its hydrological conditions have been carefully studied. Its area is about 1,250,000 square miles; the average rainfall for the year about 40 inches, for six months 20 inches. The approximate area usually given for the Irrawaddy Valley is 150,000 to 160,000 square miles; or, excluding the delta area, something more than 125,000 square miles; that is, one tenth of the Mississippi Basin. The average rainfall for 13 stations in British Burma is 133 inches annually; but mostly falling in the above mentioned six months. This, if distributed over the entire Burmese Valley, would suffice to explain the relatively enormous flood discharge of the Irrawaddy; as it is just $6\frac{1}{2}$ times that of the Mississippi, and the smaller watershed and consequent more rapid conveyance to the river channel would permit a smaller evaporation. A closer examination of the information available concerning the rainfall renders this explanation inadmissible.

Rainfalls at Station in Burma.

8. Table II has been drawn out from data supplied by the Meteorological office, Calcutta. It shows the average rainfall of the thirteen principal Burmese stations of British Burma, for a series of years, as taken from Appendix I.

Table II.

Locality.	Years observed.		Average Rainfall in inches.	Remarks.
Akyab	1860-77	18	195·83	Sea coast.
Bassein	1870-77	8	97·73	Seaport.
Henzadah...	1871-77	7	76·87	100 miles from sea. Irrawaddy Delta.
Kyoukphyoo	1870-77	8	177·51	Sea coast.
Maulmain...	1850-77	28	191·44	Near sea.
Mergui	1871-77	7	150·66	Sea coast.
Prome	1870-77	8	56·45	In Irrawaddy Valley.
Rangoon	1870-77	8	101·65	Seaport.
Sandoway...	1860-77	18	213·99	Sea coast.
Shwaygyeen	1870-77	8	152·04	Sittang Valley.
Tavoy	1870-77	8	193·05	Sea coast.
Tounghoo...	1870-77	8	74·31	Sittang Valley.
Thayetmyo	1870-77	8	51·03	In Irrawaddy Valley.
	Average.		133·61	

9. Most of these are on or near the sea coast and receive the raineloud of the southwest monsoon fresh from the Bay. Their rainfalls are abnormally heavy. The Irrawaddy Delta stations Rangoon, Bassein and Henzadah, have heavy falls of from 77 to 102 inches ; but these are much lighter than those nearer the sea coast. On receding further up the Irrawaddy Valley the rainfall still decreases, and at Prome and Thayetmyo, the only stations of Table II within the Irrawaddy Valley proper, the average rainfall varies from 51 to 56½ inches. Attempts have been made to keep Meteorological registers at Mandalay and at Bhamo, much higher up the Valley ; but these were desultory, and no records of them can now be procured. The only other known register kept within the limits of the Valley, is one given by Captain Pemberton for the State of Munipoor, which lies at the head of the Kyindwin, the principal tributary of the Irrawaddy, near the borders of Assam. He states (1) that the average rainfall for the four years 1830-33 was only 48·33 inches in Munipoor.

Division of Burmese valley of Irrawaddy. The Delta.

10. These are the only exact figures procurable at present on this important point. But much wider knowledge, generally reliable, if not so exact, is available, and from this it appears probable that the Burmese Valley of the Irrawaddy, taken as a whole, has a smaller rainfall than those figures indicate ; and that it most likely does not exceed the yearly amount of the Mississippi on the average. The drainage area of the Irrawaddy, outside the Thibetan Plateau, is shaped somewhat like an inverted Sevres vase. The delta is the mouth. The true delta extends much higher than Saiktha. The whole country behind Prome to the east as far as the Pegu Yoma Hills drains into the Hline, and the rainfall does not reach the Irrawaddy. A large portion of the country to the west of Myanoung, as far as the Aracan Yoma, also has a separate drainage to the Nawoon. The total area of the delta is thus about 18,000 square miles.

(1.) Pemberton, Captain, Report on the Eastern Frontier of British India p. 34.

11. The neck of the vase extends from Prome about 150 miles northwards to Maloon. It is about 100 miles in width, and is occupied by spurs of hills from both the Aracan and the Pegu Yomas stretching down to the river. In this rock bound portion of the river channel the rainfall is precipitated rapidly by the hill streams. The rain clouds come over the Aracan Hills after parting with a large portion of their burden against the coast and the mountain slopes near Kyoukphyoo and Sandoway. The fall at Prome and at Thayetmyo may be taken to evidence the average rainfall over this area of about 14,000 or 15,000 square miles ; and will thus be a little above 50 inches yearly. The drainage from this portion of the valley exercises a most important influence on the floods in the delta, from its contiguity and the absence of any means of moderating the rapidity of the flow. It will be seen that the great flood of 1877 owed its intensified character principally to the rainfall of this region.

The neck of the valley above the delta.

12. The body of the vase may be said to occupy an oval or nearly circular area, the centre of which lies to the north of Mandalay. It extends from Maloon far north of Mandalay and Bhamo ; but by a peculiar construction of the country and arrangement of the tributaries, the drainage from the greater part of this area only reaches the river to the south of Mandalay. All the principal tributaries of the lower part of the Irrawaddy Valley enter the river within 40 miles of each other, the highest of them, the Myit-gney, debouching 6 or 8 miles below Mandalay, on the left bank. The others, the Moo and the Kyindwin, enter on the right bank. The exact boundaries and extent of the drainage basins of these rivers are not precisely known ; but of the remaining area of the Burmese Valley, when the 33,000 square miles of the delta, and constricted portion above it have been deducted from the 150,000 or 160,000 of the whole, only 35,000 to 40,000 drain into the river above Mandalay. The other 80,000 to 90,000 square miles are distributed between the three rivers the Kyindwin, the Moo and the Myit-gney, and the central part of the basin with a few small streams.

The body of the basin of the Irrawaddy.

13. The Kyindwin Valley occupies from 35,000 to 40,000 square miles of this, or less than one half. It stretches from about latitude 22° N. to latitude 27°. This with the valleys of the Moo, lying parallel to it on the east, and of the Yau to the south, lie in much the same conditions meteorologically on the west side of the Irrawaddy. They are all sheltered by the Aracan Yoma from the rain bearing southwest monsoon. The lower parts of this tract were explored by expeditionary parties after the first Burmese war (1824-25), (1). They found the country evidencing a very dry condition of atmosphere, and the rainfall must apparently be smaller than that of Munipoor. Dr. Richardson (2) visited the lower part of the vallies of the Kyindwin and Moo rivers in the dry season of 1831. He speaks of extensive cultivation, particularly of rice, but says little to indicate the nature of the rainfall. Pemberton, however, describes all these rivers more fully ; but it is not possible to gather any more definite account of the rainfall than that the state of Munipoor, which lies near the highest point of the valley, just where it would catch the greatest portion of the rainfall, has an average quantity of less than 50 inches yearly. It is more than probable that over the whole of the area of this part of the Irrawaddy Valley on its right bank, the annual fall is considerably less than this.

Rainfall on the Kyindwin and Moo rivers.

14. It is known to be less over a large extent of the territory on the eastern side. At Mandalay itself the fall is notoriously smaller than at Thayetmyo or Prome. It has been estimated at less than 40 inches ; but more precise knowledge is desirable. South of Mandalay, in the region of which the old city

Rainfall at Mandalay and on the Myit-gney.

(1.) Wilson's Burmese War.
(2.) Richardson Dr., Journal of a Mission from Ava to Kendat in 1831.

of Pagan is the centre, the air is of a marvellous dryness. Some thousands of brick pagodas several centuries old are scattered over the site of the city, in a state of perfect preservation. The contrast observable on going northwards from the delta to Upper Burma is here intensified, and the destructive effect of the luxuriant vegetation and disintegrating climate of the lower country is markedly absent. It is said occasional showers of rain fall; but this happens seldom; and it is estimated that the rainfall of a large portion of the country is here less than 10 inches yearly. The region to the north and east of Mandalay is believed to be better watered; but the rainfall cannot be heavy, as the Myit-gney, which drains almost the whole of this country and a portion to the south, in all some 14,000 square miles, is only about 150 yards broad near its mouth. The Moo river is about 400 yards wide in flood in its lower part; and the Kyindwin is probably 600 yards wide where visited by Dr. Richardson, (1) some distance up its course. The smaller streams to the south on both sides from the mouth of the Kyindwin to Magwè, are small and unimportant, but are torrential in character, and precipitate large quantities of water suddenly into the Irrawaddy in short times; but soon resume their normal state.

Comparison of tributary channels and main river near Mandalay.

15. The paucity and comparative insignificance of all these tributaries of the Irrawaddy, when contrasted with its own stream, have been commented on by different observers. Crawford (2) remarks:—"From the town of Ava to its debouchment the Irrawaddy receives no tributary stream of the least importance except the Kyindwin," which is, "much inferior in size to the Irrawaddy."

The Irrawaddy at Mandalay,

16. The Irrawaddy itself in this neighbourhood is 3 to 4 miles broad and retains great width near Mandalay, above the points of influx of the lower tributaries. It is more confined near Sagaing, two or three miles below Mandalay, where its cross section and discharge were measured by Lt. Heathcote (3) in October 1854. He found it then discharging 316,580 cubic feet per second through a cross section of 105,300 square feet. Its cross section to the flood line was 133,800 square feet; probably this was the highest flood line of that year, which seems to have been one of ordinary flood, as no particular mention is made of the great inundations which attend very high floods like those of 1871, 1875 and 1877 in Mandalay. Now an ordinary flood rise in the delta, when the river is just within its banks, and about to spill over them, implies a discharge at Prome and at Saiktha (4) of about 1,200,000 cubic feet per second. The mean velocity of the water on the whole of the cross section of the river is about 6·5 feet per second. At extreme high flood with a discharge of from 1,800,000 to 2,000,000 cubic feet per second, the mean is about 7·5 feet per second. With the ordinary flood mean velocity the discharge at Sagaing would be 870,000 cubic feet per second, *above the entrance of all the lower tributaries.* At Mandalay itself the river broadens out, and the rise and fall in flood do not quite correspond with those of the river at Sagaing where it is narrow. Mr. Bain, Engineer to the King of Ava, has recorded the rises and falls of the river there since 1872. They are, as measured above the low fall of 1873:—

Table III.

Year	*Rise above low water Zero of* 1873.
1872 ...	... 20′ 6″
1873 ...	... 19′ 4″
1874 ...	... 22′ 6″
1875 ...	... 26′ 3″
1876 ...	... 24′ 9″
1877 ...	... 25′ 8″

(1.) Richardson Dr., Journal of a Mission from Ava to Kendat Journal Asiatic Society of Bengal 1833, p. 69.
(2.) Crawford. Journal of an Embassy to the Court of Ava, 1834, Vol. II, p. 228 also p. 3.
(3.) Heathcote. Yule's Mission to Ava, Appendix.
(4.) Stoddard Col., Report of Irrawaddy Delta Survey in 1869, p. 10.

The ordinary high flood is about 22 feet; the river being within the banks. An addition of one or two feet to this at Mandalay floods the whole city; and the effects were most disastrous in 1875, when some protective works broke. In 1868 and in 1871 the water had been some 3 or 4 feet deep throughout the city; in the former year the marks and the effects of the floods having been witnessed by the writer. Such flood rises with the increased velocity of the stream bring the total discharge of the river at Mandalay to about 1,200,000 cubic feet per second.

Conjectures as to origin of floods at Mandalay,

17. We thus have the exceedingly curious anomaly of the river discharging two thirds of its ordinary flood and much more than one half of its extreme flood from about one fourth of its drainage basin, if the theory of the Irrawaddy being confined exclusively to the Burmese valley be true. The whole of the lower tributaries with the hilly lands of its southern parts, and their remarkably rapid action in passing their rainfall into the river, would thus add from a total area of over 100,000 square miles only from one third to one half of the great flood discharges measured at Saiktha; while the remaining 40,000 square miles, whose discharging capacity is moderated and regulated by its great distance from the delta, adds the greater portion. It may be replied to this, that such floods at Mandalay are possibly only occasional and fleeting occurrences; and that it often happens, especially in rivers issuing from mountainous countries, that the flood discharge measured in an upper channel is greater than the same flood measured far lower down, through the well known moderating action of the channel. Crawford can be quoted (1) to show that when the river at Mandalay had fallen 12 feet, partially at the rate of 1 foot in 24 hours, after a day and a night's rain it remained stationary; whence he inferred that "the source of the river is not distant, nor the body of water above Ava considerable, as otherwise the stream could hardly be affected by so partial a fall of rain." Now it does not need to recur to philosophy to know that two things happening simultaneously are not necessarily connected as cause and effect. And a study of the map shows that an extremely small part of the country affected by a shower passing over Mandalay, drains into the river close above the city. The rainfall would be conveyed by a very small stream, the Madra, which could not affect the Irrawaddy perceptibly. No other streams of any magnitude occur for 120 miles northward. A range of hills on the west runs close to and parallel with the river, throwing the rainfall on that side into the Moo river. On the east more broken ranges are equally effectual in shutting in the channel, but not so closely; and it is not till reaching the Shwey-lee, the first of the Upper Tributaries of the Irrawaddy, that a heavy and continuous rainfall could here affect the main river.

The floods of the Irrawaddy above Mandalay.

18. As counter evidence to Crawford's, Col. Symes testifies (2) that on the 30th August 1795, the river had risen at Ava, which is close to Mandalay, to its utmost height, so as to threaten a general inundation. "The cause of the swelling of the waters was not apparent, as there had not fallen with us a sufficient quantity of rain to produce the smallest alteration in the river." It appears not to have been unusual, as "the Birmans who knew the exact limit to which it would rise assured us that within the memory of man, the floods had never surpassed a certain boundary." He describes the river as rising and subsiding three or four times during the monsoon months. In this, and in the duration and magnitude of each flood rise, it corresponds with the floods in the delta. The writer passed up the river to beyond Bhamo as the flood rose in June 1868. He found the river in an unusually low state during May and the first half of June, and only met the first rise *above* Mandalay about the 16th of June. The flood rapidly filled the channel and made progress by boat against the stream very

(1.) CRAWFORD. Vol. I, p. 216.
(2.) Symes Col. Vol. II p. 86 Edinburgh 1827.

slow. Before the beginning of July the banks were overflowed, and the boat passed through forests of trees in the slacker water above the banks. The river remained high during July, with slight fluctuations. An enormous flood came down at Bhamo in August. The writer was up on the hills; whence on his return in September he found the river still high at Bhamo, and within 4 or 5 feet from the banks. It was only in October that the fall commenced. The whole of the phases of the flood at Bhamo resembled almost exactly those of the delta. The August flood that had been so severely felt at Bhamo, had swamped Mandalay, and nearly inundated Prome, while it breached the new embankment at Henzada.

An investigation as to the capacity of the river in its upper channels necessary.

19. It thus appears indispensable to examine the conditions of the formation of the flood waves at Bhamo and above before any satisfactory explanation can be obtained of them as they appear in the delta. And it is necessary to determine from the capacity of the river and its tributaries above Mandalay, for we have little information of value as to the rainfall, some data as to the flood discharge of the river in these parts. Col. Yule justly points out the danger of comparing the flood discharges of different rivers in widely varying conditions, as erroneous inferences may be deduced. But on the same river and its branches, or on contiguous rivers in similar conditions, or in conditions of such diversity as may be appreciated and made to enter into the range of calculation, it may be in the highest degree useful, if it is not the only possible means of arriving at correct conclusions, to estimate and compare these discharges. In the present case no other means is available, and it is thought by attending to the principal modifying circumstances in the different rivers concerned, the most probable solutions of the difficulty respecting the Irrawaddy floods, and of other problems of not less importance may be arrived at. We have first to ascertain the capacity of the main river at and above Bhamo, and then that of its tributaries, and compare those with each other and with the discharges lower down in the channel.

The discharge of the Irrawaddy at Bhamo.

20. Bhamo is situated on the left bank of the Irrawaddy in about 24° 20′ N It is about 500 miles from the sea in a direct line; 800 by river. It lies in a great bend of the river, about half way between the two great defiles; the lower of which may be called the Bhamo Defile; the upper the Tshenbo. In both the river is constricted for several miles between spurs of hills jutting close down to its channel; but while the lower is navigable all the year round for steamers and boats, the upper is a complete bar to steamers, and is only passable for boats in low water owing to the rocks and the great velocity of the current. At Bhamo itself the river is a mile and a half wide in floods; but it is broken up into three channels by islands. Dr. Anderson describes it as a mile wide in low water. Dr. Bayfield (1) measured the left channel on 27th April 1837 at low water, and found it to be 750 yards. Mr. Strettell (2) found the same channel to be 700 yards wide in December 1873. This is the principal channel, though the others pass a large body of water. The rise from low water to high has been variously estimated; but is always remarked as great. Mr. Strettell gives it as 60 feet. The Reverend Mr. Rose personally measured it, and found it to be 60 feet. The cross-section of the principal channel alone would thus have over 126,000 square feet at high water. A mean flood velocity of 6·5 feet results in a discharge of over 819,000 cubic feet per second in this channel. The extreme high flood velocity of 7·5 feet would give a discharge of 945,000 cubic feet per second. We may safely allow one fourth of this discharge to the other channels; when the total high flood discharge at Bhamo, as at Mandalay, would be nearly 1,200,000 cubic feet. As the oscillations of the surface during flood correspond here with those of the delta, it is probable that two thirds of the total annual discharge of the Irrawaddy come from beyond Bhamo.

(1). Griffith. Journals p. 95.
(2.) Strettell Mr. The Ficus Elastica in Burma Proper 1876 p. 74.

21. Hannay (1), approaching Bhamó from Mandalay, found no diminution of the volume of the river perceptible, and thence inferred its tributaries to be much farther north. Between Mandalay and Bhamo only one tributary of importance, the Shwey-lee, enters the river. Just above Bhamo the Taping enters. Both of these are on the left bank. Above the Tshenbo defile the Mogoung river enters on the right. These three constitute the principal upper tributaries of the river. Their drainage areas are :—the Shwey-lee about 7,000 square miles ; the Taping about 4,000 ; and the Mogoung about 7000 ; in all 18,000 square miles. The total area of the Burmese drainage basin of the Irrawaddy to the north of Mandalay is between 35,000 and 40,000 square miles ; about double that of the upper tributaries, which, forming part of the area in question, and distributed over it, must be in identical conditions with the whole area, and therefore directly comparable with it as to flood.

The upper tributaries of the Irrawaddy tne Shwey-lee, Taping and Mogoung rivers.

22. Now it is a curious fact that the Irrawaddy maintains its imposing character to above the highest of these tributaries. Hannay was so struck with this that he says (1). "Before leaving the Irrawaddy I could not help contrasting its size with that of the Mogoung River ; the mouth of the latter being hardly visible from the opposite side of the Irrawaddy, which is still a fine river flowing in a reach from the eastward half a mile broad. The water is very clear and the current runs at the rate of two miles an hour. The depth varies from three fathoms in the middle to two fathoms at the edge of the river, but the banks, which are high and composed of alluvial soil, have every appearance of being overflowed in the freshes." This was in December 1835, and therefore nearly at low water stage of the river. Dr. Griffith (2), who was an able and experienced observer, thus records his impressions after descending the Irrawaddy in April 1837 with a flood wave. "The Mogoung river at its mouth is about 70 yards across. The Irrawaddy even at the mouth of the Mogoung river, and at a distance of nearly 800 miles from the sea, keeps up its magnificent character. At this point it is 900 or 1,000 yards across ; and, when we reached it, it had risen considerably, and the appearance of this vast sheet of water was really grand. Its characters are very different from the Ganges or Bramapootra, its waters being much more confined to one bed, and comparatively speaking seldom spread out.....The number of tributaries even to Rangoon is unprecedentedly small ; this tends to increase the astonishment with which one regards this magnificent river.....On the whole it is, I think, probable, that the Irrawaddy is an outlet for some great river, which drains an extensive tract of country." This astonishment has been shared by all who have visited the upper part of the Irrawaddy, under the idea generally entertained that it takes its rise at a comparitively short distance beyond Bhamo. Dr. Anderson (3) who examined the Tshenbo defile, in discussing the origin of the river coincides with Griffith and believes it to be identical with the Nukiang of Thibet.

Imposing size of the Irrawaddy at the Mogouug river.

23. Neither Hannay nor Griffith gives the rise of the river from low to high water near the Mogoung river. This is a most desirable item of information in describing a river, which is too often neglected. Dr. Anderson (3) estimated the rise in the lower part of the defile to be above 25 feet, and above 45 feet in the upper part. It is known that in every reach of a river there is one particular part called a bar which regulates the rise of the river from low to high water in that reach. It is situated always in the lower part of the reach, and the depth is smaller over it, and the rise invariably less than that

Probable discharge at the entrance of the Mogoung river.

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(1) Hannay. Capt. Selected Papers &c., 1873 p. 96.
Yules Mission to Ava Appendix
(2). Griffith Dr. Journals p, 136.
(3). Anderson Dr., J. The Irrawaddy and its sources, p. 5, 7, 8.

higher up in the same reach. The Irrawaddy appears to form a single reach from the Mogoung river to the top of the defile; hence the rise in that reach cannot be less than 45 feet from low to high flood. A forty foot rise, using Hannay's data, would give discharges of about 900,000 and 1,000,000 cubic feet per second, according as the ordinary or high flood mean velocities of 6·5 or 7·5 feet per second are used. This agrees with the results found at Bhamo and near Mandalay, and appears to justify the remarks of Hannay and of Griffith.

Probable discharge of the upper tributaries.

24. More precise information is obtainable about the sizes of the upper tributaries. Dr. Williams went several miles up the course of the Shwey-lee in the Irrawaddy plains (1). He found it to be about 200 yards wide, with a rise of about 12 feet of water in the rains. The flood discharge would thus be under 40,000 cubic feet per second. Its course in the Shan highlands above was examined by Mr. Ney Elias, (2) in February 1875, when be found it about 100 yards wide, 4½ feet deep, with surface current of 1½ knots. The dry weather discharge would thus be about 2,500 cubic feet per second. The Taping has been visited by several persons. The writer found it, in July 1878, about 150 yards wide and 10 or 12 feet deep, with a moderate current. It was then very high, and the banks were flooded in parts. Its discharge must have been under 30,000 cubic feet per second. From the sizes before quoted of the Mogoung river its discharge will not exceed 30,000 cubic feet per second. These three tributaries, occupying nearly one half the drainage basin of the Irrawaddy in the north of the Burmese valley, thus give a discharge of not more than 100,000 cubic feet per second from 18,000 square miles in flood, while the rain river is discharging 1,000,000 as alleged from the same neighbourhood, and including these tributary valleys. Either this is impossible, or the whole of the data and the estimates from them above given are entirely wrong. No other data from the same parts of contrary tendency are known, and all the persons quoted are thoroughly competent and trained observers of proved ability. We must then recur to the assumption that the Irrawaddy is an outlet for some great river of Thibet, with remote sources, and large drainage area.

The discharges of the Salween and Mekhong Rivers in latitude of Bhamo.

25. We have a means of comparing it with two other rivers known to issue from the Thibetan Plateau, the Salween and the Mekhong, which run parallel to the Irrawaddy in the latitude of Bhamo, and are there crossed by the high road from that town to the Chinese province of Yunan. Mr. Davenport, one of the members of the English Mission to enquire into the outrages on Colonel Browne's expedition to Yunan in 1875, reports (3) that the Mekhong or Lantsan was crossed by a suspension bridge of wooden planks laid on iron chains. The span is 180 feet. This was first established in 1502; previous to which a ferry boat was attached to a rope stretched across the river; but owing to the rapidity of the current the boat capsized so often, and so many lives were lost, that a wooden bridge was substituted. On this being destroyed by fire, the iron bridge was built. The party crossed this on the 25th April 1876. On the 30th they passed over the Nukiang or Salween on an iron suspension bridge of two spans 500 feet in length. One span over the deep bed was 270 feet wide; the other over a portion of the bed exposed in the dry season was 330 feet wide. Mr. Davenport describes this as a deep rapid turbid stream, bringing down like the Lantsan an enormous volume of water even in the dry season. On the 2nd May, the Mission crossed the Luenchung or the Shweylee, when it was 60 yards wide, but bringing down nothing like the volume of water of the Salween or Mekhong. He unfortunately does not give the rise from the low to high water of the two large rivers. Assuming it as 60 feet, and using the data above given with due allowance for the dry weather cross-section, the areas of these channels during floods would be about 13,500 square feet for the Mekhong and 35,000 for the Salween. Both rivers appear to be exceedingly rapid during flood and

(1). Williams, Dr. C. S. Through Burmese to Western China 186, p. 171.
(2). Elias Mr. Ney. The Valley of the Shwey-lee. Royal Geographical Society Journal, 1877.
(3). Davenport, A. Parliamentary Report on the Yunan Mission 1877, p. 23.

from the losses to the ferry boat must exceed the limits of safe boat navigation. A maximum stream velocity of 15 feet per second is probably the extreme bounds of such navigability; this would imply a mean velocity over the whole section of about 10 feet per second, which would bring the flood discharges of the above mentioned rivers to 135,000 and 350,000 cubic feet per second respectively. Taken roughly, these discharges and that of the Irrawaddy would be proportioned to each other as the figures 1, 3 and 9.

Discharge of Mekhong at Kiang Hung.

26. We are able to compare these data of the Mekhong and Salween with others for the same rivers lower down. In the year 1836 Lieutenant (now General) McLeod went from Maulmain to explore the road to China through Kiang Hung, and reached that town on the banks of the Mekhong on 13th February 1837 (1). On the 24th March he measured the river above the town. It was then 450 feet wide, more than 15 feet deep, and average current about 3 miles per hour. In the rains its channel was 1620 feet; with a rise from low water of 50 or 60 feet. The river is exceptionally broad near the town, and is much narrowed by rocky banks higher up. Its discharge in this part would probaly be 600,000 or 700,000 cubic feet per second at highest flood.

Discharge of Mekhong at Bassac.

27. General McLeod's description of the river Mekhong is confirmed by that of the French exploration party from Cambodia, (2) which ascended the river in the years 1866 and 1867 with a view of testing its navigability. The highest point they reached was Kiang Hung, which is situated in latitude 22°. They found the river impracticable for ordinary navigation above 14° N. latitude, owing to the cataracts not far from Bassac. The discharge measured at this last place on 5th December 1866 was 9,000 cubic-metres or about 320,000 cubic feet per second. They estimated its high flood discharge at nearly 1,100,000 cubic feet at the same place; and its lowest discharge at 70,000 to 100,000 cubic feet. Probably Mc. Leod's figures are somewhat too large, as the French party give its width at about 300 to 400 metres near Kiang Hung. From the crossing of the Bhamo Yunan road in latitude 25° to Kiang Hung (latitude 22°) the river has some 200 or 300 miles of course; while to Bassac it has a total of about 1,000 miles. Its drainage basin is comparatively narrow in the upper part; but widens out considerably below Kiang Hung. Its course throughout is interrupted by cataracts and rapids. In one place, the river was confined in a channel 100 metres wide. Here it was 60 metres deep. Immediately after, two difficult rapids Keng Cai and Keng Kbho were met. The water between these rapids on 5th April 1868 was only $1\frac{1}{2}$ metres or less than 5 feet deep. This was in latitude 18°, about 700 miles below the bridge described by Mr. Davenport, and where it must have a flood discharge of some 700,000 or 800,000 cubic feet per second.

Probable discharge of Salween in Lower Burma.

28. The Salween was visited by Dr. Richardson (3) on 14th February 1837. He accompanied General McLeod part of the journey above alluded to, and then diverged to the west. He crossed the Salween in latitude 18° 16′ 22″ about 200 miles from its mouth; and found it in February about 300 yards wide. Its rainy season channel was about 600 yards wide with deep banks. He reported it to be impracticable for navigation above 60 or 80 miles from its mouth. Its highest flood discharge will probably be over 600,000 or 700,000 cubic feet per second at this part. Further expeditions to determine the navigability of the river were sent in 1863. Lieutenants Sconce and Watson, examined the river beyond the British frontier. In latitude 18° 50′ they found it 300 yards wide on 30th December, with a width of twice that breadth

(1). Mc. Leod, General, Parliamentary, Papers 6th August 1869. Journal of Expedition to the Shan states p. 80.
(2). Garnier F. Voyage d'exploration d' Indo Chine 1873.
(3). Richardson Dr., Journal Asiatic Society Bengal, October 1856, Parliamentary Papers 6th August 1869, p. 113.

during the rains. The discharge here would be nearly the same as at the place crossed by Dr. Richardson. Between these localities Mr. O'Riley examined the great rapids which form the principal obstruction to navigation. It was about the same date as the last mentioned. He found the river "compressed to the width of 120 yards with the passage closed by boulders and shingle, except where the water forced its way in eddies round the bar of the larger rocks, when there was a greater depth, but no passage beyond 10 or 12 feet in breadth could be seen to afford drift room for anything larger than a small canoe. In the rains, when the river is full, boats and rafts occasionally pass the rapids without being aware of their existence. This only for a short time however, and for any practical purpose the navigation is useless."

Utility of comparing the discharges in the defiles.

29. It is important to bring a knowledge of these facts regarding the rapids and defiles of the Mekhong and Salween, where their discharges are known to be considerable, certainly over 600,000 cubic feet per second in flood, and their courses are known to have traversed several hundred miles as large rivers, to the consideration of the details of the defiles of the Irrawaddy in its upper part, where it has usually been assumed to be close to its sources. Complete and precise hydrographic measurements of these defiles are still wanting; and even if they were in our possession with respect to the channel of the river, it would be impossible in the present state of hydraulic science to calculate the quantity of water discharged in the highly irregular shaped bed in the defiles. Mention has been made of the uncertainties still subsisting in the calculations of river discharge in regular channels, and there can be no need to enlarge on the difficulties attendant on the determination of it in a rapid. All that can be done is to show that none of the upper defiles of the Irrawaddy, as far as known, is incompatible with such a discharge as has been estimated above.

The Bhamo Defile of the Irrawaddy.

30. The Bhamo Defile is about four or five miles along. It lies in a remarkable bend of the river, and is formed by high hills passing down to the channel. Accurate measurements are wanting throughout. At one place Dr. Williams measured it and found it to be 970 feet wide; when judging by the eye, he thought it only 450 feet. Close to the side the depth was over ten fathoms, but near the centre it was eight fathoms. This was in the low water of the dry season. An exceedingly strong current is found there at high flood; which is, however, surmounted by the powerful steamers of the Irrawaddy Flotilla.

The Tshenbo Defile of the Irrawaddy.

31. The Tshenbo defile is impassable at high water. It has been described by several visitors. It is said to be about 20 miles long altogether, commencing about 5 miles above Bhamo. About 20 miles above Bhamo the channel has narrowed to about 150 yards (1) near the village of Piraw which stands on a bank 80 feet high. At one point its dry weather channel is said by different observers to be reduced to 50 or 60 yards, through which contracted opening the whole body of the Irrawaddy water is forced. Even at lowest water the effect is said to be striking. The current is then almost overpowering. Dr. Bayfield said the depth varied from 11 to 25 fathoms and no bottom in the narrow parts of the defile. He went up it at low water in January 1837; and returned in company with Dr. Griffith who crossed over from Assam. They descended the river in April, the Irrawaddy rising rapidly with a flood from the north. Bayfield states that the current rushed through the defile at the rate of 12 to 15 miles an hour. The river was then not near its highest, or the passage would have been quite impracticable. As it was, it was attended by considerable danger.

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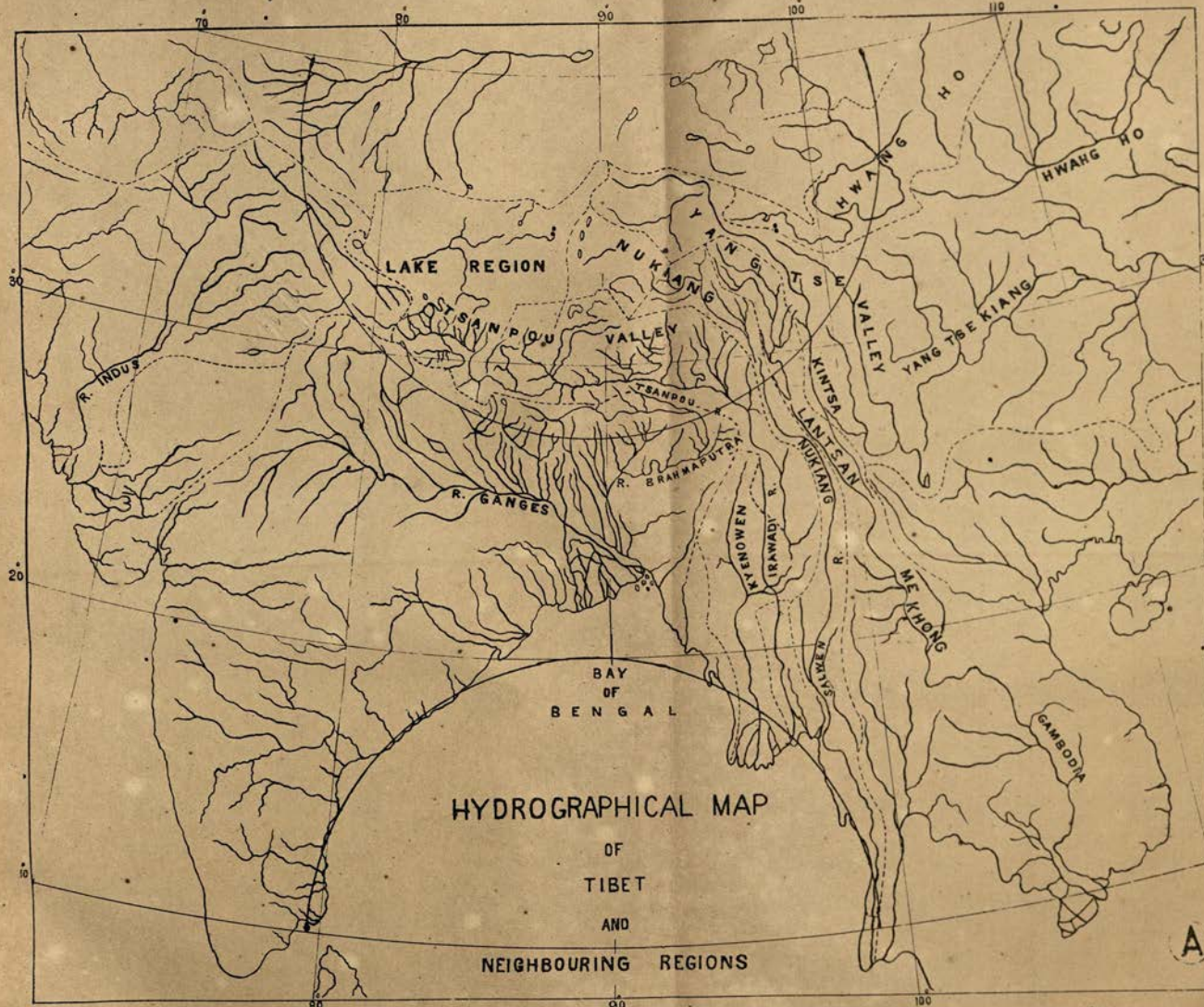
(1). Anderson Dr. J., The Irrawaddy and its sources P. 8.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LAKE REGION
TSANGPO VALLEY
NUKIANG
YANG TSE VALLEY
YANG TSE KIANG
HWANG HO
HWAHG HO
R. INDUS
TSANPO R.
R. BRAHMAPUTRA
R. GANGES
KINTSA
LANTSAN
NUKIANG R.
KYENOWEN
IRAWADI R.
SALWEEN R.
ME KHONG
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HYDROGRAPHICAL MAP
OF
TIBET
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32 A third defile, the Muntgoung, marks the extreme point of the Irrawaddy visited by a European. Mr. Strettell (1) was deputed to examine the country in this part of Burma for the India Rubber tree, and to procure specimens. He ascended the river as far as Muntgoung lat. 26° N. in February 1874, a year with a remarkably small dry weather discharge for the Irrawaddy, as the tables of discharge show. On February 3rd he found the river divided into two channels; that to the right about 50 yards wide; that to the left double that breadth, with six feet of water in the deepest part. On February 4th he says "We now found ourselves passing up a noble gorge ... Our progress was slow, and the pace continued to decrease until the crew found it was hopeless any longer depending on these poles. They jumped overboard with their towing ropes ... bent nearly double, and straining every muscle it was as much as they could do to creep along ... Another couple of hours labour brought us to Muntgoung, and here their troubles were at an end. Here the river divides into two great arms, that to the east being considerably the larger, but the rapids forbid further progress, though for boats of light draft I believe the channel is navigable for miles further north." On returning the next day he states the boat accomplished in fifteen minutes a distance that took them some hours the day before against the stream. No sufficient data are furnished of the size of the river channel and the rise and fall of the water, to permit an estimate to be made of its capacity. In one place he mentions the fact that the river, narrowing to 150 yards, inundates its banks. In another he states that the higest rise up to date (30th January) had not exceeded twelve feet. This must refer to some previous dry weather rise, and not the total yearly one. The strong current proved by his description to exist at the very lowest season (February) of an extremely low year (1874) must be followed by excessive velocities in the stream as it rushes from the hilly regions beyond. Of this country and the main channel of the rivers passing through it, we know nothing. It is sufficient at present to know from the description of this last defile, where it emerges from the hills, with those of the other lower defiles, and with those of the Salween and the Mekhong, where these rivers are known to have several hundred miles of course and enormous volumes of water in flood, that the Irrawaddy is still at this point a river of great magnitude, with a possible course of hundreds of miles, and certainly requiring a much larger drainage area than that usually assigned to it.

The Muntgoung Defile of the Irrawaddy.

33. It is a more difficult matter to distinguish which portion of the area of the great Thibetan Highlands to the north is drained by this particular river. One degree further north than the Irrawaddy has now been traced, no less then five great rivers are found running parallel to each other from north to south; the distance between the two furthest apart—the Bramapootra and Yang-tse-kiang—being less than 200 miles. Between these lie the Irrawaddy, the Salween and the Mekhong; and any adjustment of territory to one or more of these must be so arranged as to provide a suitable area for all. Various distributions of the Thibetan area have been proposed and are depicted in Plate II, all lying between the two extremes, which on the one hand, like the maps of Mr. Saunders, giving nearly the whole of the Thibetan countries as the watershed of the Bramapootra, to the theory of Klaproth on the other which gives precisely the same gathering ground for the floods of the Irrawaddy, in both cases to the exclusion of the other rivers. Neither of these can satisfy the known conditions of the rivers; nor can the one in favor with the majority of modern geographers, which assigns the Great Lake Region to the Salween, and the Sanpo to the Bramapootra; and a larger area to the Mekhong than to the Irrawaddy, which receives a comparatively trifling extent of watershed. Such an arrangement must falsify the whole of the data yet gathered respecting the Irrawaddy as well as those regarding the Salween and Mekhong, especially Mr. Davenport's on the high-

The determination of the Thibetan sources of the Irrawaddy.

(1.) STRETTELL Mr. G. W. The Ficus Elastica 1876, P. 170.

way to Yunan. But before any definite conclusion of value can be reached, sufficient must be known of the arrangement and distribution of the hydrographic systems of the Thibetan plateau to permit the true connection between its rivers and those of Indo-China to be traced. A concise summary of all that has been collected on this point will therefore be presented. A right understanding of the hydrography must be preceded by a study of the mountain systems of Thibet; so that a rough sketch of the orography of the plateau is required as a preliminary to investigating the questions raised as to the river sources.

SECTION II.

The Plateau of Thibet.

The Plateau of Thibet.

34. The Thibetan Highlands form the most remarkable mountain mass in the world. Whether considered as a congeries of mountains, or as a single plateau with subordinate mountain ranges, it is by its magnitude and peculiar features in strong contrast with every other mountain system on the globe. In mere bulk it is probable that it out measures all the rest of the mountains taken together. Spread evenly over the face of Europe, it would raise the entire continent 3,000 feet above its present level. The Alps and the Pyrenees together could only add 112 feet. Its outlying spurs to the northwest, encircling the head waters of the Indus, exceed in height, in mass and in extent the Cordilleras of the Andes.

Its form and features.

35. Its form is still more remarkable than its mass. A semi-circle of 600 miles geographical radius described about a centre on 89° 30′ E. longitude, and 37° N. latitude, with the curve turned towards the equator and base parallel to it, gives approximately the shape and position of this huge fort-like hill, which covers over 750,000 square miles to a mean height of about three miles. If the circle were complete it would somewhat resemble in outline and structure one of the great lunar volcanoes, as figured in the admirable photographic maps of the moon produced of late years. which awaken regrets that similar physiographical maps are not available for the earth's surface. Such a map would depict the Thibetan plateau in its unity and uniqueness as the most striking object, after the boundaries of sea and land and polar snow, to be seen on the face of the earth. A view taken by the setting sun would show out its circular crest rising, like that of a crater, high above the interior plains. Towards the southeast this crest is broken through as by flowing lava spread out on the plain beyond; but is continuous along the straight northern edge. Two great interior lines of mountains run across its face, each cutting off a fourth of the surface, the one parallel to the base, the other in a radial line from the centre towards the southeast to meet the former. Several minor chains run from this part through the exit from the plateau to the south and east. The half circle wanting to complete the figure is curiously reproduced in the Bay of Bengal; if this is struck with the same radius as before from a centre on the same meridian, but on the tenth parallel. The new curve almost equalizes the outlines of the Bay, which directly faces the plateau nearly at the same distance with it from the Tropic of Cancer. This apparently singular phenomenon is a case of the general law under which the greater mountain masses are ranged near great sea areas.—(1.)

Sources of information respecting it.

36. A study of the results of the explorations and surveys of the plateau and its surroundings to the latest period, permits its structure and arrangements to be known with some detail. The knowledge is more complete and precise for the exterior than for the interior of the plateau, very few travellers having traversed this portion with the means of making accurate observations. Such indications as are available for the interior territories will be noticed more fully hereafter, as being of greater interest to the present enquiry; but at present the general features of the whole will be considered. The surveys under the Jesuits in China and Thibet, with the extensions of the operations of the Grand Trigonometrical Survey of India round the West and South, combined with surveys of its Pundits in the interior, and the observations of the various travellers through the countries bordering on the plateau, have furnished accurate data respecting their features. From these, rough maps have been prepared to show separately the hypsometri-

(2.) Reclus E. La Terre.

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LAKE REGION
TSANPO VALLEY
NUKIANG
YANGTSE VALLEY
YANG TSE KIANG
HWANG HO
HWAHG HO
R. INDUS
TSANPOU R.
R. BRAHMAPUTRA
R. GANGES
KINTSA
LANTSAN
NUKIANG R.
KYENOWEN
IRAWADI R.
SAWEN R.
ME KHONG
GAMBODIA
BAY
OF
BENGAL
HYDROGRAPHICAL MAP
OF
TIBET
AND
NEIGHBOURING REGIONS
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cal, the orographical and the hydrographical arrangements of the plateau and the neighbouring regions.

Hypsometrical measurement of the plateau.

37. The colors of the hypsometrical map vary for each mile of vertical height above the sea. The black shows the crests of the great mountain ranges between four and five miles in height. The white spots in the black are the peaks rising above five miles high. These great ranges correspond with the boundary crests of the crater, sweeping along its northern edge, and round its western and southern front, and also define the two great chains that subdivide the inner face of the plateau. The northern boundary chain and the radial chain of mountains running north-west and south-east are little known, and the coloring is somewhat conjectural, but there can be no doubt that the ridges and peaks rise well into the fifth mile, if they do not occasionally transcend it. The central range is also indefinitely known for the greater part; but towards its eastern portion its heights have been accurately determined. The immense southern and eastern ranges with their continuations have been fully surveyed and their principal features fixed with great precision. The ground standing at a height of from 3 to 4 miles above the sea is shown by deep carmine. It broadens out the bases of the great ranges, and defines the outer edge of the plateau which almost everywhere stands within this zone. A rise of 1,000 feet would bring the greater part of the interior surface of the plateau into the same zone, especially the great north-western region of the lakes, which stand at a level of from 14,000 to 16,000 feet generally above the sea. The slope of the surface is invariably towards the south-east where the great rivers leave it. The lowest part of the country appears to be that between the southern and central chains. The region between the second and third miles is defined by a lighter carmine. No part of the plateau falls lower than this zone.

Contrast with its surroundings.

38. It is when contrasted with the adjacent lands that the immense elevation of the plateau is most impressive. To the north the Great Desert of Gobi, and the plains of Tartary and Mongolia, which rarely rise out of the first mile, lie immediately under the great northern chain, the Kuen Lun, which rises precipitously from them. The plateau has lately been found inaccessible from the side (1). A still greater contrast is found to the south. The plains of Hindoostan from the Bay of Bengal to the Bay of Kutch, and from the entry of the Bramapootra to the low lands to that of the Indus, never rise above the first 1,000 feet from the sea; and skirt at this level the foot of the immense chain of the Himalayas, whose ridges are generally elevated 25,000 feet above. To the east in China, and to the south-east in Indo-China, table lands lie outside the plateau at a general level of 6,000 to 7,000 feet (2); a little over the first mile. Some prolongations of the great mountain chains of the plateau run out into those table lands at heights above the second mile. From the northwest corner of the plateau two great mountain chains arise, the one the Bolor (3) passing northwards through Turkestan, and joining the Thian Shan to the north of the Gobi, the other, as the Hindoo Kush running through Afghanistan towards Persia. If there were no Thibetan Highlands, these with their connections would form the greatest mountain system on the globe. But compared with the plateau, they, if not insignificant, for this they cannot be, are relatively small. In only one or two places do they rise into the fifth mile, and the area of the ridges reaching into the fourth mile zone, marked by deep carmine, is limited. The greater portion of the crests are found within the third mile zone, but that only in the parts near to the roots in the plateau. The whole of Turkestan and Afghanistan, with these exceptions, form table lands with ridges in the second mile, and valleys in the first mile above the sea. Only one spot, with the exceptions noted, in the whole of India, China and the northern regions, reaches into the third mile, and

(1). Prejevalsky, Col. R. G. S. J. 1877.
(2). Garnier, F. Exploration d'Indo Chine.
(3). The existence of a true range running north and south under the name Bolor is disputed; but there is no doubt that mountainous country exists, perhaps made up minor ranges running east and west.

that is the Salieman Mountains, which rise to the west of the Indus, some 12,000 feet above the sea, a little higher than the lowest part of the plateau. A faint carmine color indicates roughly the mountains rising in the second mile zone, and burnt umber the hills within the first mile. There are only a few portions of the Indian Peninsula found in the second mile, one in the western ghats, and one in the Khasiya Hills above Cherrpoonje near Assam.

The northern boundary mountains. The Kuen Lun.

39. A close examination of the grouping of the mountains suggests that the nucleus of the whole is to be found in the mighty Mustagh, which, rising to a height of 28,278 feet, connects the Bolor and Hindoo Kush to the plateau. It rests on a great mass from four to five miles high. These outlying continuations of the greater ranges of Thibet include the head waters of the Yarkhand River, of the Jaxartes (Syr Darya) and the Oxus (Amú Darya); and the principal branches of the Indus. The Karakorum is the immediate link between the Mustagh and the plateau. It is said (1) to be an elevated table land without well defined ridges, and the plateau itself appears to partake of this character in the north-west corner, with great undulating plains and unimportant ridges, all lying from 15,000 to 19,000 feet high. But these shortly take distinct form and diverge into the three great mountain chains of Thibet. The northern or Kuen-lun chain is continued through the great Tantla table land and mountains, which form a nest whence several distinct secondary ranges emerge to constitute the principal mountain systems of China and Cochin China. The great rivers of these countries—the Hoangho, the Yang-tse-kiang, and the Mekhong, take their rise in the higher recesses of these mountains.

The western and southern boundaries. The Himalayas.

40. The southern and western boundary chain of Thibet consists of the several mountain ranges included under the general name Himalayas. Originally the name was applied to the ranges separating the Indus from its five great tributaries of the Punjab, and enclosing the head waters of these. The more southern mountains were known to the ancients, and are figured in Ptolemy's maps as the Imaus. So lately as 1788, in Rennell's time (2) the Himalaya was considered as a branch of the Imaus; but the name has since been extended to the mountains of the whole front of the plateau, and still further extensions are proposed. Some geographers hold that two distinct mountain chains requiring separate names, sweep round the southern edge. They point out that while the continuous line of water parting separating the interior from the exterior hydrographic systems of the plateau, lies at some distance within the southern edge, other ridges with the highest known peaks stand well out in front and dominate the plans of Hindoostan. A circle described about the before mentioned centre, and starting from the Mustagh Peak (28,258), would pass close to the majority of the great peaks of the Himalayas, Dhawalgiri (26,286), Everest (29,002), and Kinchinjunga (27,815). The whole of these stand out on prominent ridges projecting from the plateau, which are of themselves of sufficient magnitude to be considered as distinct system and chain of mountains. The main ridge, though it is believed to have some points over 5 miles high, not yet accurately fixed, offers no such impressive contrasts of height, as it rises from the already elevated table land of Thibet. The name Central Himalaya could distinguish this principal ridge (3), while that of Southern Himalayas would include the whole of the great ranges which separates the tributaries of the Indus, the Ganges and the Bramapootra on the outer slopes of the rain-gathering grounds of Thibet from each other. On the other hand it is alleged that however important these subordinate ranges may be, taken singly or taken together, they are only connected together through the main ridge and are secondary to it, and do not constitute as a whole a true mountain chain. There is only the one continuous ridge, and it is well known (4) that almost all the great mountain chains

(1). Shaw, R. H.
(2). Rennell J., Memoir of a map of Hindoostan, 1788.
(3). Markham, C. Preface to Bogle and Manning's Travels in Thibet.
(4). Reclus E. La Terre.

HYPSOMETRICAL MAP
OF
THIBET
AND
CONTIGUOUS COUNTRIES
SEA LEVEL
HILLS LESS THAN ONE MILE IN HEIGHT
MOUNTAINS BETWEEN ONE AND TWO MILES
DO DO TWO AND THREE DO
DO DO THREE AND FOUR DO
DO DO FOUR AND FIVE DO
DO MORE THAN FIVE MILES
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in the world have their highest peaks not on the crest, but on the secondary ranges, and that nothing but the magnitude of the Himalayas can entitle them to be considered different from the rest. It would seem that for highly specialized purposes it may be useful to make a distinction between the Central and Southern Himalayas; but for ordinary use the whole system of principal and secondary ranges of the southern and western front of Thibet might be grouped together under the simple name Himalayas or Himalayas Proper.

The northern Himalayas.

41. A more useful extension of the name is made by calling the great central chain of Thibet the Northern Himalaya. This has hitherto been known by the names of different isolated peaks or branches such as the Gang-disri, the Nyen-chon-tang-la, the Tarcou, and the Koiran mountains. It is now known to be a continuous range starting from the Himalayas Proper near Mount Gang-disri, the highest of mountains, according to Chinese record. Its western end has been little explored. Towards the centre the Targot rise above 25,000 feet high. At its eastern end, south of the Tengri, Nor Lake-peaks rise to 24,000 feet above the sea.

Hydrographic arrangement of the plateau.

42. This chain lies along the 32° and 33° N. parallels, and separates the great Lake Region from the valley of the Sanpo. The former lies between the Kuenlun and the northern Himalayas, and occupies fully one-half of the interior surface of the plateau. The Sanpo valley takes up nearly one-fourth of the surface, and lies between the northern Himalayas and the Himalayas Proper. The remaining fourth is occupied by the head waters of the Hoangho, the Yang-tse-kiang, and the Mekhong. In this last part any distinction between interior and exterior drainage must be arbitrary ; but the regions of Koko Nor and Tsaidam, to the extreme north-east, appear to belong to the outer system, though themselves forming portion of the plateau. There is at present no doubt as to the continuous water parting of the Kuenlun and Himalayas forming a distinct line of severance between the inner and outer hydrographic system round the entire northern, western and southern edges, to the point of exit of the Sanpo. Formerly, it was thought (1) that the Indus issued from the interior. Rennell did not accept this view for the Indus, but makes a branch of the Ganges break through the ridge of the Himalayas. Modern geographers assume that the Bramapootra issues from inner Thibet, and call the Sanpo by that name, on the theory that the two rivers are the same. The former opinions have now entirely been abandoned. The latter will be examined in this paper.

Geological history of the plateau.

43. Before proceeding to this, some points of interest connected with the orography of the plateau may be noticed. Professor Duncan (2) states that the Himalayas have been in a state of repeated uprise and subsidence while the peninsula to the south underwent few alterations. "Whilst Hindoostan was land the Himalayas were often under water and collecting sediment, and this was especially the case in the Carboniferous and Jurasic periods. During the Cretaceous age the greater part of both areas was sunken down, and there was a general uprise at the close of the period. Since then the mountain area has subsided and been re-elevated during the comparative stability of the continent to the south. * * At least five phases of sediment collecting and strata curving, upheaving and wearing, succeeded to the original condition * *. There is proof that the last great uprise and tremendous lateral incrush took place whilst the whole country was under water." The Himalayas are mostly formed of granitoid gneiss, probably the relics of the Laurentian series, one of the oldest of the known strata. The Abbé Huc in passing from the extreme north-east course of the plateau through Koko Nor and Tsaidam, and across the Tantla and Koiran ranges to Lassa in the

(1.) Rennell, Major J. Memoir of a Map of Hindoostan, 1788, p. 97, 253. &c.
(2.) Duncan, Professor P. M. Formation of Land Masses, P. R. G. Society, London, 1878, p. 68.

centre of the Sanpo valley, and from there due east towards China, found the whole country to be granitoid rocks, until he was nearly leaving the plateau. It is probable that the whole consists of the same formation united in a solid mass. It is impossible that the motion of the Himalayas could have been confined to the southern boundary range or the subordinate ranges. It is more than likely that the entire plateau was subject to the same energy of causation and moved *en bloc* in obedience to the forces operating. It seems to have protruded like a solid semicircular punch through the earth's crust; finding or making a line of fracture at a portion weaker than the rest. Probably the plains of Gobi and Mongolia to the north were in the same state of quietude as those of Hindoostan during the comparative mobility of the plateau. This seems to have carried with it the Mustagh and the double line of mountains to the west and northwest. To the east China is starred like a sheet of glass rent by a sudden blow; but the principal line of fracture follows Burma, the Malayan Peninsula, Borneo and New Guinea, and there can be little doubt that the effects of the disturbance of which the Thibetan plateau is the principal feature were felt in one continuous operation from the Caucasus to New Zealand.

Theory as to mountain boundaries of Sanpo valley.

44. It is important to note the direction of this line, or rather double line of fracture to the south-east of the plateau; especially in the mountain ranges passing through Burma, as on the relation of these to each other and to the plateau depends the arrangement and connection of the river systems of Thibet and Further India—the subject of the present enquiry. The principal theories regarding this arrangement are: 1st, That the Bramaputra is continuous with the Sanpo; 2nd, that it receives both the Sanpo and the river from the Lake Region; and 3rd, that it drains neither; the Irrawaddy being continuous with the Sanpo, and the Salween with the Nukiang from the Lake Region.

The mountains of Burma.

45. It is known that the mountain system of Burma consists of three principal ranges running nearly parallel to each other in a meridional direction. The most westerly of these is the Aracan Yoma (Yoma=backbone), which, after throwing off a spur to Assam, skirts the eastern coast of the Bay of Bengal, and is continued through the Andamans and Sumatra and Java on the direction of the fracture before indicated. This range forms the western boundary of the Irrawaddy valley. The eastern boundary is a continuous range of mountains, joined in its lower branch to the Pegu Yoma in Upper Burma, where the main chain joins the Shan table land. These are continued to the north as a distinct range—the Shan Yoma—ultimately to join the Thibetan plateau. Its eastern watershed is drained by the Salween; and to the east of this again is a continuous lofty range of mountains called in the lower part the Karennee Yoma. This forms a boundary between Burma and more eastern States. It is connected through the Malayan Peninsula to New Guinea, retaining a course parallel throughout to that of the Aracan Yoma and its continuations. With the exception of the one spur of hills to Assam all these chains in Burma with their secondary ranges have a general direction from north to south; thus determining the positions not only of the smaller separate river systems such as the Koladan, the Sittang, and the river of Siam; but those of the principal influents of the Irrawaddy and the Salween.

Connection of Burmese and Thibetan mountain ranges.

46. If the first of the above theories about the river systems, which is the one mostly held by modern geographers, is true, the great chain of the Himalayas Proper terminates abruptly in Assam, where the Sanpo issues from the plateau, by its still unknown exit. They are thus severed completely from the mountain systems to the south-east, and can have had comparatively little share in the movement to which these owe their origin. The second theory which is embodied in the maps published by the India Office with the Progress Report for 1871-72-73, requires that the northern Himalayas also have their course sum-

marily terminated by the branch of the Bramaputra from the Lake Region. The three great Yoma ranges, as well as the whole of the ranges of China, will thus be offshoots of the Tantla chain; and it alone becomes identified with the movement traceable through the Malayan islands. The third theory makes the Aracan Yoma the unbroken continuation of the great Himalayas, whose course is thus continuous from the Hindoo Kush through the southern ocean. The Shan Yomas terminating in the elevated ground to the east of the Sittang make a suitable ending to the great central chain of Thibet; while the Karennee Yoma and its continuations represent the principal branch of the Tantla and Kuenlun chains through the far south-east. There is a certain amount of correspondence in the geological features of these lines of upheaval suggestive of continuity. The peculiar strata of the later geological periods encrusting the outer flanks of the Himalayas are found in the coal and iron deposits of the Sewalik range beyond the Ganges, and are traceable throughout to the Aracan Yoma, and along its entire length to the sea. Coal and lime and iron are found from the site of Port Dalhousie at the extreme south of the Aracan Yoma and at various points throughout its course to the north of the Kyindwin; and, though sufficient is not known of the associated deposits to identify them absolutely with those of the southern flanks of the Himalayas, some of the fossils are the same, and it is highly probable they are identical; and that the Aracan Yomas underwent the changes of level simultaneously with the Himalayas, and are continuous with it. The general characters of the northern Himalayas resemble those of the Shan Yomas and of the Karennee Yomas and their continuations. It is well known from the testimony of Huc and the Pundit Nain Singh that gold abounds in the great central chain, and in the continuations of the northern chain of Thibet. It is traceable through the head-water valleys of the Yang-tse-kiang, there called by the Chinese the river of gold; and it is known also in a smaller river, the Kin Pon, in the disputed area. It is found together with other mineral deposits all belonging to the older formations, such as tin, silver, lead, mercury, &c., down the lines of the Shan and Karennee Yoma ranges, and through the entire series of islands to Australia and New Zealand on the second line of fracture. These minerals are not known on the Himalaya-Aracan-Andaman line with one or two exceptions to be afterwards noted. There is then some presumption on orographical and geological grounds in favor of the third theory. The purely geographical evidence is entirely in its favor.

Ethnography of plateau.

47. The ethnographical relations of the plateau are worthy of remark. Since the scientific researches of late years have established the great antiquity of the human species, it has been a matter of study to ascertain a clue to the mode and place of its origin. Two schools of research stand out in marked contrast; the one advocating the existence of separate centres of creation for the different races; the other—the monogenetic—asserting that the whole of the facts available tend to show that there was only one centre of origin where primitive man appeared. These facts also suggest that the first type of mankind was the yellow, and that from this the other principal types, the black and the white, have subsequently been derived. M. de Quaterfages, one of the most eminent exponents of this school, states (1) that the great plateau of High Asia was probably the cradle of mankind. "It is known that there exists in Asia a vast region surrounded to the south and south-west by the Hima-layas, to the west by the Bolor, to the north-west by the Ala Tau, to the east by the Kingchau, to the south and south-east by the Kuenlun. To judge by what exists there to-day this grand central *Massive* may be regarded as having formed the cradle of the human species". Substituting north and north-east for south and south-east as bounded by the Kuenlun, which was evidently meant, we have the great plateau of Thibet defined.

(1.) Quaterfages, M. de. L'. Espece Humaine 1877, p. 130.

48. Here, according to M de Quaterfages, the three fundamental types of man are actually found in the population grouped around the massive. The Negro races are the most distant from it, but are found pure or mixed in marine stations like the Andamans to the east and south-east. Admixtures are found in both the Gangetic peninsulas (Hindoostan and Burma-Siam); and pure or nearly pure tribes as far as Nepal, the Persian Gulf, and Lake Zarih. The yellow race, both pure and mixed, predominates on the plateau; as well as to the north, to the east, and to the south-east of it. But the white race seems to have disputed the occupation of it in past times; and its representatives are still found in the plateau and in its surroundings. "No other region in the globe presents a similar reunion of the extreme human types distributed around a common centre." Considerations drawn from the distribution of the three types of language support this view. The monosyllabic is found with the yellow race among the Thibetans, Burmese, Siamese, Cochin Chinese and Chinese. The agglutinative is represented by the Ongro-Japanese, the Dravidian and Malay, and the Turkish tongues. The Sanscrit and Iranian languages with their derivations belong to the *langues à flexion*. And it is well known that the domestic animals came from Asia where they were first domesticated.

Ethnography of adjacent countries.

49. The Burmese appear to have been one of the latest tribes to leave the plateau. It is said they are more closely connected in speech and physical characteristics with the Thibetans than any of their kindred tribes of the yellow race. Although under the influence of exposure to the climate and changes of food, the color of the skin varies from yellow to reddish and dark brown, the rounded head, the tendency to oblique eyes, the broad nose, square shoulders, and somewhat squat figure peculiar to the yellow race discriminate the Burmese from all their neighbours to the west. Mixed tribes of darker hue, with longer and straighter noses and more upright forms, have forced their way round the face of the plateau and descended the three Yoma and other ranges as Kachyens and Karens to Burma, as Khos to Siam and Annam, (1) and as Miatzu and Mantzu (2) in China. Within the last century a fresh incursion has taken place to northern Burma of Kachyens or Singphos from the Assamese slopes of the plateau, who are carrying anarchy through the whole region, dispossessing the former population and severing all connection between Burma and Thibet.

Close ethnographical relations between Burma and Thibet.

(1). Garnier, F. Exploration en Indo-Chine I. p. 392.
(2). Gill, Capt. Proceedings Royal Geographical Society 1878, p. 255.

SECTION III.

The geography and hydrography of Thibet.

49½. The countries of Thibet have for the last century and a half been sealed to open geographical research. Few travellers have penetrated to the interior, and these have either not been in a position to take exact observations, or have been compelled to do so surreptitiously and in disguised characters. Much valuable and exact information has been obtained within the last few years by Pundits of the Indian Survey Department, and this with the records of travel of Bogle and Manning and Huc and Gabet in the interior, and the observations of different observers on the outer skirts of the plateau, constitutes almost the whole of the knowledge gathered since the publication by D'Anville of his maps of Thibet and China. It is still to these maps we are indebted for our general knowledge of both countries; especially of the interior of the plateau. They are two in number, one containing Thibet alone on a scale of 20 leagues to a degree, the other on a smaller scale including China. Copies of both of these are attached to this memoir (Plate II.) The former has been used in approximating to the river areas. The latter is clearer in showing the connection of the rivers of Thibet with those outside the plateau. He shows the arrangement of mountain and river systems, and the distribution of territory which has been followed throughout in the last chapter. These maps were the first to bring to notice the most important features and peculiarities of the plateau. The great region with its numerous lakes; the northern, the central, and the southern mountain ranges, with the fan-like distribution of the minor ranges towards the south-east; the great lake of Tengri Nor to the north of Lassa and the curious ring-lake to the south; with the rivers Sanpo, Nukiang, Lantsan, Yang-tse-kiang and Hoangho, and minor river systems are shown clearly. Generally speaking, while many details have been corrected by later research, the principal features shown in the maps have been corroborated and accepted by geographers. Exception has been taken, however, to the hydrographic arrangements delineated towards the south-east part of the plateau.

Geographical research in Thibet. D'Anville's maps.

50. The Sanpo valley measured on D'Anville's map is about 185,000 square miles in extent. It runs nearly east by south, stretching over 15 degrees of longitude and lying between the 27th and 32nd parallels. He shows the river as issuing from the plateau in about five degrees east of Lassa, to enter the Kingdom of Ava as the Burmese river Irrawaddy. East of this are two small rivers, the Ken-pou and the Tchomtchou. None of these is figured beyond the frontier of Thibet; but the two smaller rivers must eventually become tributaries of the Sanpo. The former drains some 28,000 square miles on the map, the latter about 8,000. Both of these areas are included in that given above for the Sanpo. The Nukiang he connects with the Salween, or rather he carries its delineation much further south than that of the Sanpo, to a part where it is now known to be the Salween. This river he carries up to the Lake Region and connects it with the easternmost of the lakes in the smaller map; his larger one not being so clear. The greater part of the drainage of the Lake Region is shown as collected in the many lakes, without apparent outlets, or as lost in the sands of deserts. The area of this tract of country is between 200,000 and 300,000 square miles, the northern boundaries and mountain chains not being clearly defined. The area drained by the Nukiang within the plateau, as measured on this map, is about 75,000 square miles. The latest explorations introduce an important correction to the areas drained by this river. It receives the overflow from the Tengri Nor, which lake was formerly believed to have no outlet. The drainage from the northern slopes of the Targot mountains is also conveyed to

Hydrographic system of the plateau according to D'Anville.

the Nukiang, as well as that of more westerly lakes. But complete information on these points is still wanting.

Orography of plateau by D'Anville.

51. The mode of representation of mountains upon the map seems peculiar to those accustomed to the beautifully finished work of the present day; but this kind of work has always been attended with difficulties, and while opinions as to the best method are still undecided, some of the latest and finest specimens of mountain mapping show a tendency to return from the bold outlines and striking reliefs lately prevalent to the subdued and fainter styles which permit names and minor details to be distinguished. These characteristics prevail in D'Anville's work. His greatest mountain chains are etched in with short curved lines, and no distinction can be made between the large and small ranges from this. But by following a continuous line traced between the head-water streams of different river systems their drainage areas can be definitely divided, and the greater mountains discriminated. Thus no uncertainty can exist on his map regarding the principal ranges into which the great Tantla chain breaks to form the water partings between the Nukiang, the Lantsan, and the Yang-tse-kiang, and their branches. The main channels of all three leave the plateau between the 27th and 28th N degrees of latitude within the space of one degree of longitude; and are within four degrees or some 250 miles from the Sanpo. They have all a southerly direction, the Nukiang in its higher parts coming from the north-west. When the boundaries of the watersheds are traced out, the Lantsankiang is found to have an area of about 40,000 square miles allotted within the plateau between the latitudes 34° and 27° N. The head branches of the Yang-tse-kiang and Hoangho occupy the remainder of the inner surface of the plateau. Excluding these areas, that of the Lake Region and the other river valleys make up a total of between 500,000 and 600,000 square miles.

Accordance of D'Anville's views with known facts.

52. If the arrangement of the rivers within and without the plateau figured by D'Anville may be accepted, a satisfactory explanation can be furnished of the known facts relating to the floods of the Irrawaddy, the Salween, and the Lantsan or Mekhong Rivers, and a simple exposition of the most prominent data available would suffice. There seems, however, no possibility of avoiding a long and tedious argument before such a position can be taken up; as, during the present century, almost every combination and arrangement of these rivers but D'Anville's has been advanced and maintained, in some cases with pertinacity entailing recrimination and resort to the more doubtful expedients of controversy. Plate II presents most of these theories graphically, together with D'Anville's maps. Thus Rennell advocated the Sanpo being identical with the Bramaputra, and the Nukiang as the same river with the Irrawaddy. Klaproth represents the Nukiang as a tributary of the Sanpo, and turns them both into the Irrawaddy. Wilcox and others revert to Rennell's opinion as to the Sanpo and Bramaputra being identical, but reject the connection of the Nukiang with the Irrawaddy. This seems to be the prevalent theory at present; but those best acquainted with the Bramaputra cannot decide which branch of it carries the Sanpo. Griffith, and apparently Hannay, favor the idea of the Irrawaddy being a great river, from their knowledge of it in its upper part, but do not decide which portion of Thibet it drains. Dr. Anderson takes the same view, but maintains Rennell's notion of the connection of the Nukiang and the Irrawaddy. Mr. Saunders turns the Sanpo, the Kenpou, the Nukiang, and the Lantsankiang into the Bramaputra, and cuts off the head waters of the other Indo-Chinese rivers. Even if any of these views could explain the phenomena, each one adopted would require the grounds of the preference for it over the others to be stated in full; and in justice to the other opinions advanced, the reasons for rejecting them to be explained. So there seems no alternative in an enquiry of this kind, but to examine at some length all the evidence on the subject available. This enquiry, when originally undertaken, started from Dr. Anderson and Major Rennell's

view, as the most probable point of departure, but after careful consideration it has led to the conclusion that that position is untenable; and that the only possible explanation of the whole of the facts in our possession is an entire reversion to D'Anville's arrangement and to the geographical representations contained in his maps (1.).

D'Anville's views have been unduly neglected. Necessity for examining these shown.

53. It is not known upon what grounds D'Anville's views were originally believed to be incorrect; or whether in any case a formal testing and condemnation of them has been held. No such enquiry of an extent and with means of verification sufficient to warrant the adverse conclusion come to can be traced by the writer; to whom it seems that D'Anville's claims to consideration have been generally quietly ignored, and his extremely valuable services to geography unduly neglected. If this be so and a more complete research should re-establish his title to be held as an authority on the subject, a rehabilitation of much importance to Indo-Thibetan geography will have been achieved. Such enquiry must necessarily include a discussion of three separate sets of circumstances: 1st, The material used by M. D'Anville; 2nd, his qualifications and opportunities for using those materials; and 3rd, the results of the tests supplied by travellers in later years, through some of the countries of Thibet delineated by D'Anville.

The sources of information. The Jesuit geographers and the Llamas.

54. The sources of the information from which his maps are compiled are mentioned by D'Anville in the preface to his New Atlas of China (2); and they are described more fully by the Père Regis in Du Halde's great work upon China (3). The Jesuit missionaries had for many years enjoyed the favor of the Chinese court. Members of the mission accompanied the Emperor to Tartary in the 17th century and recorded valuable observations. A complete survey of the whole of China Proper was entrusted to them, and was executed in the years 1708 to 1718. They commenced at the great wall, and ended at the provinces of Hoei-tcheou and Honquang. The principal places were fixed by astronomical observations, and detailed surveys of the whole country were conducted with great minuteness and accuracy. The present maps of China are based on their work; which, when the instruments used and the difficulties arising from the time and place are considered, must be esteemed one of the most wonderful upon record. The training the missionaries themselves underwent, their extended experience and the scrupulous care they employed in their own work, made them excellent controllers of the labors of others in similar fields. At that time Thibet was nominally independent; but was really subject to Chinese influence. A resident embassy was sent from Pekin to Lassa to reconcile contending parties; and the spirit of geographical research imbued by the Jesuits induced the Emperor to order the members of the embassy to prepare a map of Thibet. The result, embodying two years labor, was presented to the Père Regis in 1711. He found the data too vague to be utilized in a map like that being prepared for China; but it furnished detailed information of the highest interest not to be found in any map then extant. The Emperor, on learning this, ordered a new map to be prepared. Two Lamas were carefully trained by the Jesuits to take and record accurate observations, and were sent from Sining Foo to Lassa, and thence to the head waters of the Ganges to bring back some of its waters. In 1717 a new map was completed from their surveys and placed in the hands of the missionary geographers. It was found incomparably better than the previous ones, but still had serious faults. The Jesuits accordingly subjected it to further improvements before they adopted it as a basis to work from. They checked the position of Lassa. They compared the distances of places shown with those obtained

(1). It is the more necessary to do this as a late writer thus attacks D'Anville. Speaking of the Thibetan Rivers, he says. "It is only when we come to such maps as D'Anville's, which were drawn up for the express purpose of upholding a flimsy hypothesis (the connection of the Sanpo with the Irrawaddy), that we find them boldly brought down through the most extraordinary windings to their desired course."

(2). Nouvelle Atlas de la Chine.

(3). Du Halde.

from numerous itineraries of the routes through the country. They consulted intelligent travellers who had been over the roads, and applied the severest tests the immense resources at their disposal permitted, to bring the whole to a state of completeness and accuracy. The finished data and the maps prepared by them were subsequently placed at the disposal of the central mission at Paris. It was thus after a two-fold purification by competent agents that the materials eventually came to D'Anville's hands.

D'Anville's high repute as a geographer.

55. An account of D'Anville and his work is given by M. Vivien de St. Martin (1), Honorary President of the Geographical Society of France, in the introduction to the beautiful atlas now being issued by Hachette. From this it may be gathered that D'Anville was not a mere recorder of others men's views or labors, but that he brought to bear on all that passed through his hands the original research and discrimination characteristic of the modern scientific geographer. Born in 1695, he early manifested signs of genius, and at twelve years of age was devoted to geography. The Abbé de Longuerue availed himself of this taste, and entrusted him with the preparation of some maps for a description of France, published in 1719. This work brought D'Anville so much to notice that the heads of the Jesuits in Paris confided to him in 1729 the materials sent from China by the missionaries, in order to prepare the maps to accompany the Description of China by Du Halde. M. de St. Martin says: "This atlas of China is particularly remarkable in this, that up to the present, with the exception of some nautical surveys of the coasts and some very limited reconnaissances in the interior, it is the sole authority that we have for the map of this vast country of Asia." D'Anville further, after some twenty years or more of work, issued his grand atlas. His labors mark out an era in the history of geography, from the beauty and delicacy of his maps. "But beyond this material beauty his superiority depends on two principal points; the science of detail, and the critical employment of his materials. It is he who was the first to restrict the indications of his maps within the rigorous limits of known facts. Nothing is permitted to fancy, very little to hypothesis. Where the information ceases the maps remain blank. It was a great merit at that time, it is worthy of note even now." It was thus to a specialist of the very highest excellence that the final sifting of the material for the maps of Thibet was entrusted. The judgment above pronounced on M. D'Anville is by one pre-eminently qualified by his own geographical labors to form it. There is, therefore, a first presumption in favor of the representation of the maps, which is not to be laid aside except on definite grounds. And nothing but a wide divergence between the details of the maps and those furnished by subsequent travellers can lower D'Anville's claims to rank high as an authority on all geographical matters pertaining to Thibet.

Subsequent researches afford means of checking his maps. Four lines of travel selected.

56. The number of travellers who have penetrated to the interior of Thibet is very small. In order of time those who have left records of their journeys are:—1st, the Chinese authors of "The Description of Thibet;" 2nd, Messrs. Bogle, Turner and Manning; 3rd, MM. Huc and Gabet; and 4th, the trained Pundits of the Survey Department of India, who have gone in various disguises. Other travellers like Dr. Hooker, Colonel Prejevalsky, Mr. Cooper, Mr. Shaw, Mr. Hayward, Capt. Gill and others have visited the outskirts of the plateau, and in some cases got within the interior; but their most valuable contributions are to the exterior watershed of the plateau. The lines taken by the former travellers are admirably suited to test D'Anville's maps. Lassa, as is well known, is the political and religious centre of the plateau; and, in a more literal sense than roads to Rome, all Thibetan roads lead to Lassa. It lies a short distance behind the Himalayan range on the northern side of the Sanpo valley, and very nearly on the meridian line bisecting the plateau. The routes of all the travellers to the interior mention-

(1). De St. Martin, M. Vivien. Atlas Universelle, Hachette, 1877. Preface.

ed led to it. The first one is that of MM. Huc and Gabet, which leads from the extreme northeast corner to it in a line deviating from the direct by curving towards the east to avoid crossing the several mountains in their lower parts. It passes over the high Tantla table-lands and then comes in a southerly direction past the Tengri Nor to Lassa. A second line leads from the province of Little Thibet to the north of the central range, and passes parallel to it through the length of the Lake Region, and past the Tengri Nor on the last line to Lassa. This was followed by Pundit Nain Sing. A third line runs in a westward direction from Lassa to China, breaking ultimately at Tsiamdo into two routes, the southern and central high roads from China to Thibet. The latter is closely described and an itinerary given in the description of Thibet. The Abbé Huc also describes it. The first line he travelled is the northern high road from Pekin to China. Pundit Nain Sing has given details of a fourth line from the extreme west of the Sanpo Valley down the whole length of the river to Lassa, and from there to the furthest point yet reached on its course to the east, whence he crossed the Himalayas to Assam. Other lines of less importance have been followed from India through the valleys of Nepaul, Sikhim, and Bhootan to Lassa and to points within the Thibetan frontier, as well as across the Sanpo valley to the northern Himalayas and to the Tengri Nor.

Huc and Gabet's travels in north-eastern Thibet.

57. MM. Huc and Gabet were members of the Jesuit Mission to China, who, though precluded from following the geographical studies of their distinguished predecessors, were enabled by a prolonged residence in China, and a previous study of the Tartar, Mongolian, and Thibetan languages as well as the Chinese, to pass through Thibet in the costume of Lamas without being detected. Their purpose was purely religious; as they desired to establish in Lassa itself a mission with trained native disciples to continue the work. After long preparation in monasteries with the Mongols they departed for the Koko Nor, or Blue Lake, which lies at an elevation of 10,000 feet in the great fertile plains of the same name forming the first flank of the plateau. This they describe as an immense salt lake with tides like the ocean; but unnavigated by any boats. Here they joined the great Thibetan embassy returning from conveying tribute to Pekin; and took their place unchallenged among its attendants. They followed and crossed the Pouhain Gol, a feeder of the Koko Nor, not shown by M. D'Anville. He shows a mountain range to the south of Koko Nor running east and west. This Huc makes no mention of; but Colonel Prejevalsky, who travelled the same route in 1872, describes a ridge of high mountains (1) rising from the southern shore of the lake and running 345 miles towards the west. Thence on the 15th November 1845 they arrived amongst the Mongols of the savage country of Tsaidam. D'Anville shows the Tsaidam river under the name Tchoiteng. He makes it flow from east to west, contrary to all other rivers in this part; and in this he is followed in all late maps. Neither Huc nor Prejevalsky note the direction of its flow; probably as it was frozen over, but this peculiarity is worthy of notice as it is represented as going towards a mountain chain. The plain of Tsaidam is said to be a great marsh about 1,000 feet lower than the Koko Nor plains. South of it lies a mountain range figured without a name by D'Anville; but called Bourhan Bola by Huc, and Bourkhan Bouda by Prejevalsky. The height of it is not given; but, as Prejevalsky states that the plains immediately to the south are at 14,000 to 15,000 feet elevation, this must be much higher. Its height is much exceeded by those of the Chuga and Gourban Naiju ranges, continuations of the Kuenlun, which reach into the region of perpetual snow. Huc mentions crossing the head waters of the Hoangho at two day's distance from its source. D'Anville makes this river rise exactly in the same place. From this last range to the Yang-tse-kiang, or as it is there called the Mourouï Oussou, is about 58 miles, with a low range intervening. This river had already acquired considerable size. Huc calls it here a *grand fleuve*. It was then

Prejevalsky's travels.

(1). Prejevalsky, Colonel. Proceedings Royal Geographical Society, London, 1874, p. 79.

frozen over, holding in firm grip some 50 wild oxen that had attempted to swim it It is shown by D'Anville as having traversed a considerable distance after receiving several large branches at Huc's crossing. Colonel Prejevalsky penetrated no further than this river.

The great Tantla mountains and table-land.

58. MM. Huc and Gabet experienced the most severe sufferings in coming thus far. The country passed over was a complete desert. Vegetation grew scarce as they advanced; water and pasturage for their animals failed. It was the depth of winter. Driving winds, falling snow, and bitter cold overcame the caravan. M. Gabet fell ill The road for some days looked like the excavations of a vast cemetery. Human bones and carcasses of animals strewed the ground to prove that previous caravans had fared no better. From the Mourouï Oussou southwards the ground continued to rise, and they gradually ascended to the foot of the highest table land in the world. Unfortunately they had no means of measuring heights; and beyond knowing that the previons range of Chuga had risen, an enormous mountain, from plains themselves 15,000 feet high; and that the great Tantla range they were now approaching is still higher than the others, and therefore likely to be well into the fifth mile, we cannot estimate the figures. The road became worse, and the cold more intense as they ascended. Numbers of the pilgrims were frozen, and were left, still living, by the way. More than forty were thus abandoned. At last the Tantla mountains were reached; and in six days of painful effort they ascended to the top. Here, fortunately, the weather changed; a serene and bracing air with warm sun restored health to the invalids. They were twelve days crossing, and four descending. The descent was long, brusque and steep. They went, as on a gigantic staircase, where each step was a mountain.

The sources of the Salween.

59. From the Tantla to Lassa the ground gradually lowers. They crossed the Na Ptchu river at a village of the same name. Na Ptchu has the same meaning as the Mongol Kara Oussou or Black river. D'Anville shows the Kara Lake and Kara Oussou in this place. In the large scale map they are not quite joined to the Nukiang river, but approach it closely. In the smaller map they make one with it. The former is most likely an error in engraving. Nain Singh's later researches make it known that the river from the lakes is certainly continuous with the river to the east of them which D'Anville represents as the Nukiang and Salween. He shows the great Tantla mountains in his accustomed form, as a series of curved lines, unbroken throughout by any water-course from the Kuenlun to the latitude of Bhamo, where it separates the Salween from the Lantsan or Mekhong.

Corrections to D'Anville's maps.

60. Huc mentions a map of M. Andrivean Gonjou he had with him which he found very correct. This map must have been taken from D'Anville's; and the map attached to Huc's work corresponds in great measure with the latter, on which the whole route can be traced. No corrections of importance have been made to the map in this part by subsequent researches. The Tengri Nor Lake has been found to be of smaller size than figured by D'Anville. He makes it about 75 or 80 miles long, by 45 wide, lying from east to west just north of latitude 31°. The latest map shows it nearly 50 miles long by 25 wide lying from east to west just south of 31°. In both cases it is slightly west of Lassa. Huc crossed the Koiran mountains, shown by D'Anville, before reaching that city. There is thus far a reasonable correspondence between Huc's observations and the details of the map.

Nain Singh's travels in north-western Thibet.

61. It is convenient to leave Huc's further route for the present, and turn to the last journey of Pundit Nain Singh on the second line mentioned. A full account of this, with a map, has lately been published in the Royal Geographical Society's Journal for 1877. He is the most distinguished of the Pundits

trained to explore, in disguise as merchants or pilgrims, under the directions of the Indian Survey Department, those countries in the neighbourhood still impenetrable by Europeans. He had formerly been to Lassa. He accompanied Sir Douglas Forsyth's mission to Yarkand; and on the return of the second mission volunteered to explore northern Thibet. He left Leh, the capital city of Ladakh, on the 15th July 1873, reaching Noh on 3rd August. Noh is near the eastern end of a series of Lakes known at present under the name Pangong. Their nearest point is about 11 degrees west of Lassa; their extreme length from east to west is about 100 miles and greatest width not more than six or seven (1). Now 200 or 300 miles from Ladakh and nearly 10½ degrees west from Lassa, D'Anville shows a series of three lakes connected together whose extreme length from east to west is about 100 miles; and greatest width about fifteen. The eastern two are called Mapama, Conghe. If these names were combined they would philologically result in Pangong. They are on the outer drainage system of the plateau, some streams running into them from the east, and a distinct ridge of hills separating them on the map from the interior. In this the system corresponds with the Pangong series. Major Godwin Austen has proved that it formerly drained westward into the Shyok; and that its waters at the eastern end are sweet, evidently from fresh water received, while at the western they are brackish. It is to be mentioned that D'Anville's representation of the Ganges head waters in this part is entirely wrong. It is, however, comparatively of late years that any exact information was obtained either of this or of the Indus.

The Lake Region.

62. From Noh the Pundit appears to have followed a direct line nearly east by south till he passed the north side of the Tengri Nor, and joined the high road to Lassa. He shows on this line a number of small lakes receiving drainage water but having no outflows. Some are bitter, but others sweet. A line drawn from the Mapama Conghe Lakes on D'Anville's map to the north of the Tengri Nor passes through several small and large lakes. It is, however, impossible to identify these with those of the Pundit, as there must be much confusion of names. No indication is given in either case whether Mongol, Tarter, Thibetan, Chinese, or Hindoostanee names of places are used, and it is possible that any or all of them may have been employed. But within four degrees west of the Tengri Nor, there lie on D'Anville's map, almost on the same parallel with it, but on a line slightly curved towards the north, six distinct lakes distributed pretty evenly over the distance. And on the same parallel of 31½° N. distributed on a similarly curved line over the same number of degrees are found six lakes discovered by Nain Singh in his adventurous journey. They are, as a rule, larger than those of D'Anville; and a few very small ones are also shown. Taken in order from the Tengri Nor, they are named by

The Pundit.	D'Anville.
1 Mokien	... 1 Siranbosa.
2 Kyaring	... 2 Taksai-raki.
3 Chikut	... 3 Anedsai.
4 Daru Cho... ...	... 4 Tongong.
5 Nyangzin Dungche	... 5 Tankin Yamso.
6 Dangri Yum Cho...	... 6 Chouro Jondso.

Possibly a comparison of the meanings of these names might result in an identification of them. This would not in any way lessen the value of Nain Singh's services to geography; and probably, in the opinions of most, would lend additional lustre to the honors he has gained by vindicating the work of his Thibetan predecessors.

(1). Trotter Capt. Royal Geographical Society's Journal 1877, p. 91.

63. There is the same difficulty about names with the minor mountain systems on this route. Both maps are covered with small ridges on the line; but there is one larger range common to both. D'Anville shows the Tarcou mountains as a great range running from east to west in latitude 31½° N. to the north of the six lakes just described, and compelling the drainage through them to go ultimately to the Tengri Nor. Nain Singh makes the Targot Mountains run east and west to the south of these lakes in latitude 30½°, thus forming part of the main chain of the Northern Himalayas. The drainage here flows northwards; part of it to a large lake called Chargut Cho, which was not seen by Nain Singh, but placed by him conjecturally two degrees east of Lassa. That portion of D'Anville's map is blank; but near the meridian of Lassa is a large lake called the Pouca, connected with three others, including the Kara or Black Lake. From information gathered by Nain Singh it appears that the drainage from the Targot mountains ultimately reaches the Nak Chu Kha river, which is identical with the Na Ptchu of Huc, and therefore with the Nukiang of D'Anville, and thus is the head water of the Salween. Captain Trotter states that Nain Singh learned that the Na Ptchu became a large river, but that the data furnished were not satisfactory. It is evident, however, that he has been able to introduce important amendments to this portion of D'Anville's map; while at the same time he has corroborated its principal features in its least detailed and least accurate part.

The Targot mountains and the sources of the Salween.

64. Nain Singh furnished other information of importance. He shows that the boundary ridge on the west of the plateau where crossed by the road from Leh to Noh rises in one place to 18,420 feet high, and in another still higher. The general elevation of the plain is from 14,000 to 15,000 feet, but it often rises higher, especially in going eastward, where the average elevation appears to be above 3 miles. He crossed one pass on the eastern part of his route 18,170 feet above sea level; and measured some peaks near the road to the south, the highest of which was 22,800 feet high; and some still higher of the Targot group, too far off to be measured, he estimated as at least 2,500 feet higher or about 5 miles high. He visited the gold fields of Thok Daurakpa on this central chain of Thibet; and from enquiries found that other gold fields existed on the same mountain line. The fields were not esteemed very valuable, but the fact that they exist is so, for comparison with the gold yielding ranges further to the south and east. Only a single sheet of cultivation was met with in 74 marches. Here a rich crop of barley was being gathered in September at an elevation of 15,240 feet. Boundles plains of pasture land existed, affording magnificient shooting, and support to nomad Mongols and Khamtas, supposed to be of the same tribal origin as the Khamtis of Upper Burma.

Heights of the northern Himalayas.

65. From the Tengri Nor to Lassa Nain Singh followed a route previously surveyed in part by another Pundit. To the east and south of the lake are mountain ridges shown by D'Anville as branches of the Koiran under the names Tarcola Toluinouron, and Larkin. These were found by the Pundits running from southwest to northeast, exactly as shown by D'Anville, but different names are given. The passes range from 16,000 to 18,000 feet; the peaks rise as high as 23,900 in Ninjinthangla to the south of the lake. The arrangement of the rivers, influents of the Sanpo, on the road from Tengri Nor to Lassa is identical, or nearly so, in D'Anville's map and in the Pundit's. A small meridional range just north of Lassa is found in both. Lassa itself is situated exactly the same in D'Anville's and in the very latest and most accurate map published with reference to the Sanpo, the minor rivers and all the surroundings. It is almost exactly on the same parallel as shown by D'Anville. This is most important as Rennell challenged the accuracy of the Lama's surveys. He found that D'Anville showed it in about 29° 25′, and he removed it

Confirmation of D'Anville's correctness where impugned by Major Rennell.

to 30½°, or one degree further north. It is now known to be lower than 29° 40'. Rennell's opinion of D'Anville may be quoted. He says (1) "I should be wanting in candour and in respect to his memory, should I forbear to do justice to his nice discernment in placing the entry of the Ganges into Hindoostan, by inference from Delhi, almost at the very spot where I have now placed it, from actual survey" Rennell would have been the first to admit the high character of D'Anville's work in Thibet, had he possessed the checks we can now use.

The Lassa Bathang Road.

66. The line from Lassa to China passing due east is the great high-road to Bathang and Lithang. It divides at Tsiamdo where a branch turns southward to Yunan. The former road was followed by Huc and Gabet on their return from Lassa; and appears to have been that used for the military operations from China to Thibet. While the materials for the map of Thibet were being gathered by the Jesuits, a Chinese army under General Win Phou marched (1718) from Lathang to Lassa, and subjected the government to that of Pekin. A large part of Thibet was incorporated with China Proper. Two officers attached to this army drew up from all available sources a description of Thibet. This was published in 1791 with a preface by Lou-houa-tchu, a commissary of the army of occupation, who was with it for five years. The work was translated into Russian by the Archimandite Hyacinth of Pekin; and thence into French. It was subsequently corrected by Klaproth and published at Paris in 1831 with notes and additions. It contains an elaborate description of the whole country, with notices of the people, their customs and history. In the information it gives it illustrates the kind supplied to the Jesuits and used by D'Anville in his maps. This, however, only applies to the parts actually visited by the authors, when their statements are clear and precise; and may be taken as samples of the details furnished to the missionaries by the intelligent travellers they consulted. The other portions of the work are more vague, but contain a large amount of information presented in a useful form.

Chinese description of Thibet.

67. Taking Lassa as a centre they describe in succession the principal roads leading from it to the four quarters of the compass. A detailed enumeration of the mountains, lakes, rivers and towns is given. The four provinces of Thibet Proper, which do not include the Lake Region nor that to the northeast of the Tengri Nor inhabited by Mongols, are, Ngari, Tsang, Ou and Kam, taken in order from west to east from the head of the Tsanpo Valley to Bathang. These they define and take Canton by Canton describing the principal features and giving their local names and relative positions. They further group these features together and generalize from them. The great Himalayan range to the south is described under the name Thoungla with high and steep summits covered with immense masses of never melting snow. The northern Himalayas is said to extend from the highest of all mountains Gang-ti-sri to Ngari in the far west of the plateau. The Kuenlun is called in its western part the Gambola. From the information thus given Klaproth was enabled to construct a small map of the country. It is, doubtless, of the same kind and value as that originally presented to the Jesuits, but offers very crude and inaccurate conceptions when compared with D'Anville's. The scientific training of the Lamas who gathered the data for this, with the repeated scrutinies and additions it received before it reached him account for the difference; but in both cases an immense storehouse of detailed and accurate knowledge appears to have been open for both to draw from.

Sources of information numerous and of high value.

68. The question as to how this thorough knowledge of one of the most difficult countries in the world should be so accessible and familiar is immediately answered by a reference to the habits of the Turanian races, or at least those branches of them which seem to have last settled from the nomad

(1). Rennell Major, Memoir etc. p. 220.

state. The practice of pilgrimage is universal. Mongols, Thibetans, Tartars and Indo-Chinese have it in common. It is at present interwoven with their religious feelings. Often, in Burma, any pretext suffices for journeys of hundreds of miles on foot or by boat. Recurring festivals to noted pagodas draw intelligent observers from all parts of the country. A constant circulation of the wealthier and poorer classes alike goes on. Even trivial circumstances of ordinary life bring about transmigrations unusual to more western peoples. The same state of things seems to have existed from time immemorial in Thibet; where in addition to shrines of local fame, the perpetual attractions of the sacred city of Lassa intensify both the feelings and the practice. Worshippers from all parts of the plateau gather there. A further source of information is provided by the educated Lamas themselves. They go from monastery to monastery to study and teach; often settling in places far from their homes. A vagrant class of these priests possess undeniable opportunities for acquiring this geographical knowledge. Huc says (1) "These vagabond Lamas visit all countries accessible to them, China, Manchooria, Khalka, the kingdom of southern Mongolia, Ouraing-ha, Koko-Nor, the celestial mountains both north and south, Thibet, India and even Turkestan. There is no river they have not traversed, no mountains they have not climbed, no Grand Lama to whom they have not made homage, or people with whom they have not lived, and whose manners, usages and language they do not know." The universal hospitality of the Turanians dispenses with all care for their sustenance. They enter houses freely and are made welcome to food and shelter. When these are not forthcoming they sleep foodless near rocks or in the open. Desert and mountain and city are alike to them, they never rest. No return seems expected from them in teaching or preaching, but doubtless they narrate their experiences of other lands and peoples, thus stimulating a curiosity which can only be satisfied by accurate infomation. And the continual embassies from the subordinate states to Lassa and to Pekin must supply men competent to note and describe precisely and accurately the routes they have traversed. There could thus be no lack of intelligent informants either to the Jesuits or to the Chinese authors.

Huc's testimony to the exactness of the Chinese itinerary.

69. The itinerary of the high road from Lassa to Sithang gives the greatest value to the description of Thibet. It takes the route from east to west. Every minute detail is recorded for the benefit of travellers. Each hostelery, with the nature of the food and accommodation, and the character of the people are described. The places for changing horses, the ascents and descents of mountains, the crossings of rivers by boat or bridge, the state of the roads and the distances traversed are mentioned. A copy of this work in the original was placed in Huc's hands on leaving Lassa for China. He speaks of the work as of remarkable exactitude, but complains of its dry and laconic descriptions. Its bald statements of fact are only of interest to those going by that route, or who specially occupy themselves with geographical questions. To the last, however, it is of the very highest interest not only for the direct value of its statements, but as evidence of the kind of data used by D'Anville in the preparation of the map of Thibet. The minuteness of the details recorded, with their verification by Huc, afford complete tests as to the credibility of that map in the neighbourhood of the parts held most open to doubt.

Features of Lassa Bathang road.

70. What is wanting to the Chinese account, Huc supplies. His narrative vivifies the dry details of the road, and presents, with the realistic force of a Defoe or a Bunyan, the incidents and features of the journey. The two old men with broken health and defeated enterprize were expelled from Lassa, and conducted under escort to China by the central route. They had to travel over one of the roughest countries in the world. Nothing was to be seen but chains of snow clad mountains traversing their path, intersected by horror striking gorges, with wild rapid-flowing

(1) Huc. I, p. 190.

rivers, and cataracts and defiles. What the mountains are may be inferred from his description of a plain (1):—"The high regions we followed after crossing Chor-kon-la are considered in those parts as a plain. 'From here to Alainto' said the Thibetan escort, 'there is no mountain, the road is like that,' and they showed us the palm of the hand. Meanwhile, they added, it is necessary to use precautions, as the roads are sometimes narrow and slippery. Well, this was the road of the plain, as flat as the palm of one's hand. Immediately the summit of Chor-kon-la was passed, a long series of frightful gulfs was met, bounded on both sides by vertical mountains rising like walls of living rock. The traveller contours profound abysses, following at a great height a road so narrow that the horses scarcely find room for their feet. When we saw the cattle of the caravan pass on this horrible path, and we heard the surly mutterings of the waters below, we were seized with fright and descended from our horses. But every one cried to us to remount. The horses, they said, being accustomed to such journeys, had surer feet than ours; and we must let them go at will, grasping our saddle firmly of, and not looking about us. We commended our souls to God and joined the column. We were soon convinced that it would have been impossible to keep our equilibrium long on the rough and sliding earth. An irresistible force seemed always to be drawing us to these unfathomable abysses. For fear of vertigo we held our face towards the mountain, the sides of which were sometimes so straight and even that there was no room for a horse's feet. The passage was then made on trunks of trees lying on piles driven horizontally into the mountains. The sight alone of these fearful bridges made an icy shiver run through all our limbs. Yet we had to go on; for it was impossible to descend or go back."

Huc's journey on it. Comparison of itinerary and his travels with D'Anville's map.

71. Five principal ranges, prolongations of the Northern Himalayas and of the Kuenlun, had to be crossed before reaching Bathang on the Yang-tse-kiang. They are separated by profound valleys; but, as no instrument of measurements were with them, Huc can give no figures for the heights. But gauged by their feelings and the fatigues inflicted, these must have been immense. Their strength was almost exhausted. Two fellow travellers, father and son, were successively found dead in their palanquins by the way. The commander of the escort succumbed in the end. All combined to give a sombre background to the narrative; but a kindly sympathy with sufferings in others, and a quaint humor in relating their own misfortunes, somewhat relieves the prevailing hue. They left Lassa on the 15th March 1846, crossing the river Bo-chou (Kal-tiou D'Anville), which runs into the Sanpo. After many days journeying in the same valley, which grew more tortuous and barren, they crossed the high mountain Louma Ri. The road over was easy and brought them to the town of Ghiamda (Tchamta, D'Anville). The itinerary states that Ghiamda is in a low hot valley, where rice is cultivated in irrigated fields. Thence an impetuous torrent and a frozen lake were passed. Both are figured in their proper positions by D'Anville. A great range of mountain called by him the Samronca, but with the local name Shari, running nearly north and south was crossed. The itinerary describes it as covered with perpetual snow. It must thus be over 18,000 feet high (2). The ascent and descent are precipitous. The crossing was effected by roads and no-roads across snow and glaciers, only passable in fine weather, and brought them from the valley to that of the Ken-pon. This was not at so low a level as the last and contained a savage and desolate region, both land and inhabitants lacking culture. Another great range of mountains, the Chor-kon-la, had to be crossed with height and difficulties rivalling the last. Here D'Anville shows the Chari con-la mountains, which in his usual manner when indicating a principal range, he notes by M. M. after the name. Minor mountains and subranges are shown by a single M. This range separates the valley of the Nukiang from that of the Kenpon; and is traceable through his map as a continuation of the Koiran mountains, or Northern Himalayas, to where it en-

(1) Huc. II, p. 432.
(2) Strachey Sir R. Hooker Sir J. H.

ters Burma as the Shan Yomas. The itinerary gives the Chinese name Lou Koang-la as well as the Thibetan Chor-kon-la Gang-ri, and describes its crossing as the most difficult of the whole road. From here they descended to Alaito, by the Kin Keou river, or Gorge of Gold. The word Kin or Ken, common to this, to the Kenpon, and to the Kinsna indicates the presence of gold in the streams, which is also found in the whole of the ranges of mountains continuous with the Northern Himalayas. Here Huc remarks upon the gold in the sands. The Tanda mountain next had to be passed. There is a confusion between Huc's account of this and that of the itinerary. The remark which is applied by this to the Chor-kon-la, as being the most difficult to pass, is quoted by Huc as relating to the Tanda. In any case this seems to have been a grave obstacle to the caravan. It is covered by snow. They halted at the important military station of Chobando, shown as Chou-pu tou by D'Anville, in the highly cultured valleys of the Nukiang. Thence by sinuous roads winding through mountains, and forests of holly and pine they reached the broad, deep and rapid river Souk. The Souc is shown by D'Anville as the principal northern branch of the Nukiang, passing a town of that name. He also marks a large town called Lourondson on the route followed by Huc. This is not mentioned by the latter, but it is noted in the itinerary. A bridge called Pont Sapia on the map shows where the high road crosses the river. The itinerary states that this is simply Somba in Thibetan, or the bridge. Very curiously a few days before Huc's arrival this bridge had been carried away by the river, with two men and three bullocks then upon it. The climate here is said to be warm and little variable, and the country fertile. It is probable that its height above the sea does not much exceed two miles. Ten miles farther on the map the road crosses a stream, passed by Huc on a suspension bridge.

Comparison continued.

72. A dividing range of mountains is traceable on the map between the valleys of the Nukiang and the Lantsan continuously from the great Tantla mountains in the north to the southern limits of the map. This chain bifurcates in latitude 34° N. to enclose the head water streams of the Lantsan; the principal two of which meet in about 31¼° latitude to form the main channel of the Lantsan there called the Dsatchu. In the fork between this and the minor stream the Pontonsong or the Om-chou, lies the fortified town of Tsiamdo, called by D'Anville, Chamtou. He does not name the mountain range; but it is called by Huc and the itinerary the Wa-ho and it is famous for its fogs and avalanches. The snow is perpetual, and neither bird nor beast nor human habitation is found upon it. From this a descent is made to the river Lanthan-kon or Lantsan, a smaller stream than either the Om or the Dsat as it rises only in 32¼°, but giving its name to the subsequent course of the river. Huc crossed this on his way to Tsiamdo. From this place to Batang he followed the line of the Lantsan river on an extremely difficult road passing over projecting spurs of mountains, deep ravines, and bridges suspended in the clouds. The itinerary speaks of very high mountains surmounted by still higher peaks. The town of Djaya (Tsiia of D'Anville) is about halfway on this road. Before reaching this Huc came across limestone hills with enormous caverns and quarries of fine marble. He had previously met nothing but granitic formations in his journey. The streams in the village contained large quantities of gold dust, which was extracted by the people. He hardly notices the mountain separating the Lantsan from the Kinsha-kiang; but it is duly figured on the map; and it is said by the itinerary to be covered with snow all the year round. From Batang Huc followed a northeast route to Lithang, crossing an elevated mountain covered with snow, which reminded them of the worst parts of their past journey.

Heights of mountains crossed on road.

73. We are enabled to judge what the mountains passed over by Huc in his trying travels must have been from those lying in the neighbourhood of Bathang and Lithang. Captain Gill (1) visited this part of the country in 1877. He found the pass of

(1). Gill Capt. W. J.—R. E. Travels in Western China, &c., Proceedings Royal Geographical Society, 1878, p. 255.

Ta-so across the range projecting between Lithang and Bathang to be 15,600 feet above the sea. Near this is the high peak of New-da, 22,000 feet high The water-parting between the Kinsha and the Lantsan is crossed at 14,500 feet. As the ranges are crossed by the road at a farther distance from the main chains than the Wa-ho, Chorkonla and Shari passes traversed by Huc, it is probable that these are at much higher elevations than the above figures; and from the perpetual snow on their summits cannot be below 18,000 feet high.

Confirmation of D'Anville's accuracy.

74. The correspondence between the route as described by Huc and the Chinese authors of the itinerary, and as depicted by D'Anville, is exact and satisfactory. The numerous details of villages and hostelries are, of course, left out of the maps, but the whole line can be traced step by step, and feature by feature. The distances, directions and relative positions agree. There is nothing to show that unusual precautions had been taken by the Jesuits to ensure accuracy on this particular route. The great roads to China are doubtless better known to the Chinese than the rest of the country, but the data were originally collected by the educated Thibetans to whom the other roads to Lassa must have been equally familiar.

The head waters of the Mekhong.

75. Neither Huc nor the itinerary supply precise information as to the sizes of the rivers Nukiang and Lantsan-kiang were crossed by the Lassa-Batang road. But both these and their branches were spanned by substantial bridges in latitudes 30° to 31° N. The itinerary states that the Thibetan name corresponding to the Chinese Nukiang is Djouk-ba, answering to Huc and D'Anville's Souc. The French translation speaks of it as a *fleuve*, while it calls the Lantsan a *riviere*, thus noting a distinction in their sizes similar to that found on the Bhamo-Yunan road. The branches of the Lantsan are enumerated and their sources described. The one comes from Djoungba; the Dzat rises in the Canton of Kieou-jon. The united river is said to flow through Yunan. The road to Yunan follows its course almost throughout in the lower part below Bathang, and the adventurous traveller, Mr. Cooper, was turned back on it as far south as Weeseefoo in about latitude 26½°. D'Anville's map corresponds entirely with the accounts of this river both in its derivations, its relative size, and in its direction and position on leaving the plateau. There can therefore be no justification in representing this river in any other way than as the head waters of the Mekhong or Cambojia river, which is known to correspond in size and position with it, up to nearly the above latitude. It is familiarly known to the Chinese throughout the whole upper part of its course, and the drainage area of its higher valleys may safely be taken from D'Anville's map as a first approximation.

The head waters of the Salween.

76. The Nukiang appears to have been made a matter of greater doubt than the Lantsan. The itinerary (1) describes it as a broad river with steep banks, and so rapid a current that it cannot be crossed by boats. It elsewhere states that the Nukiang is the southern boundary of Yunan. On D'Anville's map the boundary line is run along its channel from about latitude 25° to latitude 30°. M. Klaproth in a note to the itinerary states that there appear to be two Nukiangs, one as shown by D'Anville, which he makes a tributary of the Irrawaddy, the other to the south and west of the Sanpo. There is nothing in the itinerary itself to indicate this; although Klaproth professes to draw a small map from the account given showing both the Nukaings; and it has since been proved that the western Nukiang is identical with the Om tchu of D'Anville's map. It is a matter of extreme importance to decide whether the Nukaing, known in its upper part as Souk or Djouk to the Thibetans, is the same river as the Nukiang known to geographers on the Bhamo-Yunan Road as the Salween. D'Anville's representation of the river in the larger map appears to be taken entirely

(1) Itinerary p. 42. Description du Tibet.

from the Lamas' surveys. These cease for the Nukiang at about 26° N. latitude, some five degrees south of the Lassa-Batang road. Names of places in the neighbouring country are carried nearly as far south as the 27th degree; but the river channel itself is clearly shown much further and corresponds exactly with the position of the river serving as the western boundary of Yunan in the small scale map which includes China. Now Yunan was included in the survey made by the Jesuits themselves. The fathers Fridelli and Bonjour commenced this province; but the latter dying, father Regis took his place and finished it in 1715. There is clear proof that their survey extended to the west and south of the Nukiang as shown in the Lamas map, and connected its course there with that now known to be the Salween. The Bhamo-Yunan road passes near Sanda, the capital of one of the Chinese Shan states in the Taping valley, long included within the boundary of Yunan. It is situated some 60 miles west of the Salween, the boundary and the survey limits lying some 20 miles west of this. The Jesuit survey shows Sanda a few miles to the north of the Taping river, and 10 or 12 below the junction of its principal branches, one from the north, the other which the high road follows coming from the north east. It also shows the Shwey-lee, a larger tributary of the Irrawaddy to the east of the Taping. Mr. Davenport records the crossing of this last exactly in the position shown, where it has the name Luenchun. The present writer was appointed engineer to the exploration party from Bhamo to Yunan in 1868, and in this capacity drew up a map from the survey made and from numerous itineraries obtained from intelligent travellers and traders in all the neighbouring parts. Some of these were themselves able to sketch maps of the country fairly and it was found possible to show the general features such as streams, mountains, villages, &c., with tolerable accuracy. On subsequently comparing this with D'Anville's map the trustworthiness of the Jesuits work in this locality was apparent. Indeed their map has claims to be applied as a test to the work of casual explorers wherever the handiwork of the Missionaries themselves can be traced. And from the circumstance that the Nukiang river is continuous in the map far beyond the limits of Thibet and the Lamas' survey, through the region included in the survey by Father Regis, while none of the more westward rivers is so continued, an assurance is given that it was from actual survey alone that the Nukiang is identified with the Salween.

Exact correspondence of D'Anville's Map with the latest information concerning Yunan and eastern Thibet.

77. The high character of the work the Jesuits themselves executed; the rigorous scrutiny and tests they subjected the Lamas work to; the further corrections the materials furnished received from D'Anville's hands; and the subsequent corroboration his results have received from the itinerary and Huc's travels on the line crossing the upper parts of the Nukiang and Lantsan place the identity of these rivers with the Salween and the Mekong respectively above discussion or doubt. All other testimony has only strengthened this position. The relative sizes of the Mekhong and Salween where crossed by the Bhamo road, agree with the descriptions of Huc and the itinerary of their sizes on the Batang road, and with the drainage areas deduced from D'Anville's map and Nain Singh's subsequent researches. No evidence has ever been adduced in the other direction or tending to invalidate these conclusions. It is then a matter for enquiry how it comes that the highest authorities of the present time have adopted views either adverse to D'Anville's representations of these rivers; or have considered them to remain so doubtful as not to be worthy of adoption in modern maps. The beautifully finished maps issued by the India Office, London, with the Progress Reports for India for 1871-73, show both the Upper Lantsan and the Nukiang as feeders of the Bramaputra. These maps companying writings of the Secretary to the Royal Geographical Society, Mr. Clements Markham, without protest on his part, and therefore with the sanction of his approval. But it appears from an original record (1) of the author of the maps

Contrast of the definite and trustworthy information of D'Anville's map and the vagueness and confusion of modern maps of this region.

(1.) Saunders Mr. Trelawny, The Mountain and River Basins of India, 1870.

Mr. Trelawny Saunders, Geographer to the India Office, that he considers the question as to these rivers still an open one, only to be settled by scientific exploration. It seems difficult to understand how, with the evidence available, and which is generally known to geographers, such uncertainty can still subsist. The latest published maps of the Government of India do not leave the matter in a more satisfactory condition. The last edition of the north-eastern boundary map of India (1875) shows the Salween taking its rise as a small stream at Tsiamdo, the fortified town described by Huc and the itinerary as lying at the junction of the two branches of the Lantsankiang, which is already a large river at that place. The head waters of the Lantsan itself arise in the latitude of Tsiamdo, but farther to the east. Names are given to each branch and the courses are figured clearly throughout, except in short portions shown by dotted lines, as though great precision were wanting here but secured elsewhere. Tsiamdo is in latitude 31°. The Irrawaddy, which in the latitude of Bhamo we have found to be nearly three times larger than the Salween, and nine times than the Mekhong, is made to take its rise three degrees lower than Tsiamdo. No great tributaries are figured as flowing to the Sanpo from the north and east. We are thus thrown into hopeless confusion if we rely on the latest maps published by authority, which is not lessened when we find a competent judge of the subject like Dr. Anderson, the naturalist member of the 1868 Mission, while acknowledging the necessity of providing a great feeder for the Irrawaddy as suggested by Dr. Griffith, claiming the Nukiang to be that feeder, through the great eastern branch of the Irrawaddy.

The authority of the Jesuits and D'Anville definitively settles the question as to the Upper Mekhong and Salween rivers.

78. The very tedious examination we have been compelled to subject the maps of D'Anville to leave, in the writers opinion, no possible doubt on the subject open any longer. The river of Tsiamdo is the Mekhong, and rises several degrees farther north. The Imperial survey of China stands as an authority for the principal facts guaranteed by it on precisely the same grounds as other National and Imperial Survey made since, and the connection of the Salween on the Bhamo road with the river at Point Sapia appears as fully proved as that of the Rhine at Basle with the Rhine at Strasburg; and it is in the highest degree probable, if not absolutely certain, that it is the river which drains the eastern part of the great Lake Region. If once D'Anville's map is rejected as an authority on these points, all seems delivered to conjecture; and it is a pity, if there is real grounds for this, that they have not been stated. At present every other arrangement of the mountains and rivers than that given by him is opposed to all the evidence we have; and if adopted to explain a series of facts like floods of the Irrawaddy is misleading, and may be mischievous.

Importance of accepting these conclusions.

79. For if it is admitted that an important part of the discharge of this river comes from the Thibetan plateau, and we strive to determine the meteorological conditions attendant on a great flood season or a small one, we may find highly diversified states between the drainage areas of, for instance, the Sanpo and the Nukiang. And according as we adopt either or neither of these for the gathering grounds of the Irrawaddy floods, a different explanation of these in the past, and a different basis of anticipation for the future, is required. A very great step in advance is made if we can absolutely exclude the Upper Lantsankiang, and the Nukiang with the Lake region, from entering as disturbing elements in the calculation. A process of exhaustion of the remaining areas of the Sanpo and the Kenpon and Tchitomtou rivers will then lead to definite conclusions.

Travellers to the Sanpo valley.

80. The items of evidence from the statements of travellers to the valley of the Sanpo in Thibet are comparatively numerous. Mr. Markham has given resumés of these in the Preface to the journals of Mr. Boyle and Mr. Manning, and in the Royal Geographical Society's

Journal for 1875. Mr. Boyle headed an embassy from the Governor-General of India, Warren Hastings, to the Grand Lama of Teshu Lombo in 1774. Captain Turner visited Thibet in 1782. Mr. Manning went to Lassa on his own account in 1811. All went by the Bhutan valley. The first Pundit sent by Colonel Montgomerie and Colonel Walker reached Thibet by the Kerong pass from Nepal in 1865. After visiting Lassa he explored the Sanpo valley to the sources of the river at the Miriam La Pass. The second Pundit reached Shigatze on the Sanpo in 1871. The third accompanied the second to Shigatze, and from there struck across the valley to the Northern Himalayas, crossing them by the Khalamta pass, and returning by the Tengri Nor Lake and Lassa.

Nain Singh's journey to the Sanpo valley.

81. Nain Sing, the first Pundit referred to, is the same one who lately came from Leh though the Lake Region to Lassa. His earlier journeys and the final portion of his last furnish information regarding the line No. 4 passing through the known part of the Sanpo valley. He started from Nepaul on the 20th of June 1865, passing the frontier town of Kirong (Tchiron D'Anville), and through the Chinese post of Jonkajong, which, Mr. Markham states, is probably the Arijong of D'Anville's map. He was turned back, and had to cross the Gola pass considerably to the westward. Here a pass is marked Tala by D'Anville. On the 2nd September he reached the Sanpo and passed to its northern bank at a level of 14,200 feet above the sea. Journeying on this side he crossed the Charti Sanpo from the northern chain, shown as the Sanki Sanpo by D'Anville ; thence he crossed a range marked Tchipong on the old map, into the valley of the Raka Sanpo, a river with a long course parallel to the Sanpo into which it falls below Janglaché. This river is clearly marked on D'Anville's map, exactly in the position described. Janglaché or Tchanglase (D'Anville) is on the right bank 190 miles below the former crossing. At Phuncholing lower down (Keltan Ponsonclaim, D'Anville) the river is crossed by an iron bridge. They reached Shigatze (Jikse) on 29th October ; 11,800 feet above the sea. From here, they turned south to Giansu (Tchiantse), passing through Painain (Painam). Giansu was visited by Boyle, Turner and Manning. Nain Singh followed Mr. Manning's route from there to Lassa by a road marked on the map by dotted lines. This crosses a spur from the Himalayas by a pass 17,000 feet high. Thence he descended to the great ring Lake 13,700 feet above the sea and encircling an island mountain. Mr. Manning did not discover this peculiarity of it, which is shown distinctly by D'Anville. He crossed the Sanpo at a height of 11,400 feet, and arrived at Lassa on the 10th January 1866.

The northern parts of the valley.

82. Very little knowledge is added to the above regarding this part of the country by the other observers ; and some 85 miles of the course of the Sanpo south of Shigatze would be quite unknown but for D'Anville, who gives mountains, streams and towns on what must be taken to be as good evidence as that tested. He supplements and completes the outlines derived from the later surveys, and presents a comprehensive view of the whole, such as could not be obtained from them. Some little information was obtained by the explorers to the Nothern Himalayas. The Pundit, in 1871, ascended a river nearly opposite Shigatze called Shiang-chu. He found the town of Chamnamrien as shown by D'Anville, and visited also by Mr. Boyle. The party crossed the Khalamba pass (17,200 feet) and reached the river Ghaika called Tarcou by D'Anville. The peak Ninjin Thangla was fixed (23,900); and the level of the Lake Tengri Nor found to be 15,200 feet above the sea. In none of these explorations has any diversity of consequence been noted from the map of D'Anville.

The south eastern parts of the Sanpo valley.

83. The continuation of test line No. 4 passes from Lassa down the Sanpo valley and across the Himalayas to Assam. Pundit Nain Singh after his arduous journey through the Lake Region, passed down the Sanpo river to a lower point than before reached by Indian or English surveyors. He made

Dhejar (Jienio, D'Anville) in one march. Thence crossing a range (figured on map) at 16,620 feet, he descended to Samayé (Samie) near a rivulet flowing into the Sanpo. Both town and rivulet are shown. He went down the Sanpo for two marches, crossing it on 30th November 1874. He estimated the width of the river to be 500 yards, with a very sluggish stream, nowhere deeper than 20 feet. The valley is here several miles across. A bank of sand 1½ miles wide lies in the bed of the river. This is covered in the rains when the river is in flood. He left the river near Chitang (Tchiacar? D'Anville), but fixed its course for a considerable distance by taking bearings. Captain Trotter in describing the Pundit's labors expresses as his deliberate judgment that "the course of the river thus determined is fairly accordant with that shown in Du Haldes' map of Thibet.". Du Haldes' map was prepared by D'Anville. Nain Singh is of all the explorers the one whose work is best fitted to test D'Anville's map by. Like the Lamas of the Jesuits, he received a thorough preliminary training in competent hands. He had previously explored the Sanpo from its head to Lassa; and the Lake Region from Leh to Tengri Nor and to Lassa. He has been deservedly honored for his geographical labors by first receiving a gold watch, and latterly a gold medal from the Geographical Society. But a still higher honor he has achieved is that of having vindicated the works of his Thibetan predecessors in the same field. Their names are unknown, and the results of their labor has been undeservedly neglected; but nothing can be more satisfactory than the tests applied and the complete re-establishment which must ensue from this. In almost every case where it has been possible to verify the map, it has been found "fairly accordant." In some cases it is more, it is wonderfully accurate; and can be used to check the statements of travellers, or the theories of geographers.

The western p rts between the Sanpo and Bramaputra rivers.

84. The Pundit went from Chitang up the rich and fertile Lalung valley. Numerous villages and monasteries were scattered about. Two large towns, Naitong and Chukya Bhutang, were passed. D'Anville shows a small river here with two towns, Oitong and Schoukia Pouran. The Kaiking Pass, 16,200 feet high, was crossed about 60 miles from Chitang. South of this for 60 miles to the Kya-Kya-la pass, the road traverses a high undulating plateau, bounded to the west by a snowy range running due north and south; just here D'Anville shows a ridge with the general direction due north and south, and 60 to 70 miles long. Further south he shows the Omtchou flowing 40 miles nearly due east, and then turning south-east to join the Sopra Cachou, disappear with the southern limits of the map. The Pundit, after leaving the last pass, "followed a stream which, under the name of the Sikung Sanpo, flows for 40 miles nearly due east, and ultimately turning south-east, runs nearly parallel to the Upper Bramaputra, which river it is said to join in Assam. (1)" Passing the important towns of Chona Jung and Tawang-Chukang, he reached Udalgiri in British territory on the 1st March 1875. Tawang-Chukang is probably identical with the Tareng-dsong of the map, the last place shown.

Confirmation of all details in D'Anvilles map by Nain Singh's researches.

85. There is thus a marked coincidence throughout, with the exception of the Targot mountains, removed one degree too far north, between the indications of the map, and the various routes traversed by this Pundit. We have also seen that this close agreement obtains between it and the information from other sources, wherever it has been possible to apply a test. The result must be most surprising to those who have had to construct maps from partial surveys and from routes furnished by travellers, however intelligent these may be. And if the extent and difficult nature of the country represented is considered, and it is remembered that the test lines are almost co-extensive with the map, the admiration excited must engender a thorough confidence in the remainder of D'Anville's work. Now, is this confidence to terminate with the limits of later research, or are we

(1). Trotter, Capt., Narrative of the Pundit, Journey, Journal of the Royal Geographical Society 1877.

entitled to extend it in a reasonable measure to those regions of the plateau which have not yet been reached by modern exploration? The portions more immediately neighbouring Lassa, and between it and China have been found to be accurately shown to almost the smallest detail. Mountain chains, ranges, and sub-ranges, are shown with precision in direction and position. The emendations in the latitude of Lassa by Rennell have been found unnecessary. Towns, monasteries, rivers, streams, lakes, and even a bridge are shown exactly where found a century and a half after by later explorers. Can we accept, with the same assurance we now possess as to these details, D'Anville's representations of the remaining part of the course of the Sanpo, with the various features depicted by him?

D'Anville's authority not final on the question of the identity of the Sanpo and Irrawaddy rivers.

86. The maps show the course of the Sanpo over four degrees east of Lassa and three beyond where the Pundit left it. This carries it almost to the meridian of the water-parting between the Bramaputra and the Irrawaddy. Some towns with names—Dsanlarken, Thamca, Nai and Chai,—and others unnamed are marked on its course to the end; and beyond this he states that a little further are the frontiers of Ava, which State he elsewhere declares it to enter as the Irrawaddy. This was from the information he had received. He does not actually join the Sanpo to the Irrawaddy in the map, and from this it must be understood that the surveys of the Lamas extended no further than the portion shown by him. And it may thus be said that his connecting the two rivers is a matter of inference, and not from knowledge of facts. He has not even the evidence for the identity of the Sanpo and the Irrawaddy, that he had for that of the Nukiang and Salween, and Lantsan and Mekhong rivers. His authority, therefore, it can be argued, may be accepted when based on statements of fact themselves unknown to us, but interpreted with his proved conscientiousness and practised skill; but the same weight cannot be given to it when it is manifestly only a personal opinion or theory founded on the reasonableness of certain views; and all that can be expected is, that the evidence in favor of those views be carefully examined, with due deference to his authority. This seems the only legitimate position to take, since the majority of modern geographers have come to the conclusion that the Sanpo is one of the feeders of the Bramaputra, and has no connection with the Irrawaddy.

Arguments in favor of it.

87. In favor of D'Anville's views the principal arguments are:—that the Sanpo from its known dimensions in Thibet is capable of supplying the enormous discharge of the Irrawaddy proved to be in its channel at Mandalay, at Bhamo, and at the mouth of the Mogoung river; and that no other river or drainage area in Thibet, or to the north of Burma is capable of doing so. The only data we have as to the size of the Sanpo are:—1st, Father Giorgi (1) says that the iron bridge between Janglaché and Shigatze is composed of chains of 500 links, each one foot long. Lower down, where Mr. Boyle crossed it on the 7th November 1774 near Shigatze, he found it, the waters being low, about the breadth of the Thames at Putney. The channel was not formidable, but the water was far from rapid. After crossing the river they rode over a large sandy bank, which was overflowed in the rainy season. Mr. Manning (2) crossed it about 100 miles lower down, at a town standing on the bank of the river. From this town he descended down to the sandy shore, and found a large and good ferry boat ready to waft them over the stream, whose width was considerable. This was in the dry season of 1811-1812. The Pundit Nain Singh (3) crossed the river on the 30th November 1874, near Chitang, at the lowest point of its course yet reached. He estimated its width then at from 350 to 500 yards, with a depth of 20 feet. Its current was sluggish; near the bank it was about $\frac{2}{3}$ of a mile per hour. Its cross-section would thus be about 20,000 square feet and discharge

(1). Giorgi, Father. Rennell's Memoir, p. 226.
(2). Manning, Mr., Narrative, p. 251.
(3). Nain Singh Pundit, P. R. G. S. 1877, p. 341.

over 30,000 cubic feet per second. The rise from low to high water is not given. But he states that the valley was here several miles across. "On the left bank of the stream was a stretch of sand fully 1½ miles in breadth; the whole of which was said to be under water in the months of May, June and July; during which season the river is much flooded, both on account of the increase of the water from the then rapidly melting snows, as well as from the rain, which falls in considerable quantities from April to June. "This account is fully corroborated by those of Boyle and Manning. The river is very broad with sandy banks flooded in the rains. Assuming a rise of 15 feet from low to high water, the total cross section could not be less than 100,000 square feet; and using the high flood average velocity found for the Irrawaddy of 7·5 feet per second, the discharge cannot be less than 750,000 square feet per second at this place. In countries of steep declivity it is known that the rivers and streams are invariably shallow. Possibly the rise may be higher, however, than 15 feet, and the velocity greater than that given, but from the circumstances described the quantity found is likely to be often reached. The drainage area of the Sanpo valley comprised between Chitang and Bhamo would add considerably to the flood volume; though the length of channel would have a moderating action on the passage of each flood wave.

88. The discharge of the Irrawaddy at Bhamo has been found approximately to reach over 1,000,000 cubic feet per second. In about the same latitude the discharges of the Salween and of the Mekhong reach in high floods probably to 350,000 and 135,000 cubic feet respectively; or taken roughly the flood capacities of the three rivers are as 9, 3, 1. The drainage areas measured on D'Anville's maps, which we have seen to be approximately correct, are 185,000 square miles for the Sanpo; 75,000 for the Salween; and 40,000 for the Mekhong within the plateau. The researches of Pundit Nain Singh show that the area of the Salween should be somewhat increased, to include the drainage to the north of the Targot Mountains. Probably 90,000 to 100,000 square miles will be nearer the truth. The drainage areas of the Kinpon and of the Tchitomton are together about 35,000 square miles; the remainder of the Sanpo thus draining some 150,000. The valleys of these smaller rivers lie parallel to the lower course of the Nukiang within the plateau, and are contiguous with it. They are thus subject to closely similar meteorological conditions; and have nearly related geological formations. It is therefore quite impossible that they could contribute a discharge three times as great as the Nukiang from less than half its area; or more than twice that of the Nukiang and Mekhong combined from less than one third their area. Indeed it is obvious that the whole valley of the Sanpo must be situated in different circumstances relative to the rain-bearing clouds from those of the other parts of the plateau to permit it to supply the immense volume of water passed down the Irrawaddy at Bhamo.

The Sanpo drainage area is the only one that can supply the great discharge of the Irrawaddy.

89. Several distinct circumstances require to be considered before an adequate explanation of this phenomenon is obtained. Firstly, it is necessary to add the area of the valleys between the plateau and the Bhamo-Yunan road to the previous areas. About 30,000 square miles are required for the Irrawaddy, and 10,000 each for other rivers; bringing the totals for the Irrawaddy north of Bhamo to over 200,000 square miles, for the Salween to over 100,000 and for the Mekhong 50,000; or, roughly taken, in the ratio to 4, 2, and 1. There is still a vast disproportion between the discharges of the rivers and their watersheds which only altered conditions can explain. The principal valley of the Sanpo and the northern part of Burma lie directly across the path of the principal branch of the south west monsoon winds, which, upon losing a large part of their moisture on the outer flanks of the mountains lining the coasts of the Bay, are heated and ascend over the crests. The work performed in the ascent uses up this heat, and they pass over the high ridges with the point of saturation

Further enquiries as to Sanpo area and Irrawaddy floods.

lowered so that they are ready to part with a further supply of rain, especially against the slopes of the further mountains. But this process cannot be indefenitely repeated with the same result. When once in the upper Irrawaddy-Sanpo valley the winds are at a great elevation ; and, though the rainfall here is attended with a warming of the air which again rises to pass to the Lake Region and Nukiang and Lantsan valleys it has lost much of the moisture, and any subsequent fall of rain is likely to be less copious than the preceding ones. Hence the pecular features of the Lake Region, with its innumerable lakes with unimportant tributaries and generally no outlets. And hence also the comparatively small discharges for sub-tropical rivers like the Nukiang and Mekhong within the plateau. Their directions are also nearly parallel in their lower parts to that of the prevailing winds, and are thus less likely to receive as large a supply as if they lay across it.

Circumstances influencing the discharge of the Irrawaddy.

90. The distance of the centre of the drainage area from the point to where the flood is measured has a considerable modifying effect on the rate of discharge. If no water were added to the channel of the Irrawaddy to the south of the plateau, and none lost from it through percolation, evaporation or other causes the quantity discharged per second in a varying sudden flood would be lowered at successive points such as the Mogoung River, Bhamo and Mandalay on passing down the channel. This is due to the unequal velocities of the different parts of the stream. The nearer to the gathering ground, therefore, the river is measured, the more acute will the flood be. The centre of drainage area is much nearer Bhamo on the Irrawaddy than it is for the Salween on the same latitude. These various causes unite in producing a disproportionately large discharge for the Irrawaddy, compared with the watersheds of the Salween and Mekhong ; but at the same time the necessity of such an explanation proves that none of the suggested arrangements of the river systems can be valid which neglects fully to account for these floods. Either their existence must be disproved in the upper parts of the river, in such volumes as we have been considering ; or a full explanation of their presence must be afforded. We can hardly resort to the ancient theory that the water is distilled from the sea in the interior of the earth. and passed through caverns and crevices into the river channel to return to the ocean. And yet no other resource is available if, as supposed by modern geographers, the Sanpo is a feeder of the Bramaputra. This theory is held with so much consistency and unanimity by high authorities that it is necessary to examine the evidence in support of it in detail.

SECTION IV.

Major Rennell's hypothesis as to the connection between Sanpo and Bramaputra Rivers.

91. The first suggestion as to the identity of the Bramaputra with the Sanpo appears to be due to Major Rennell of the Engineers, Surveyor General in Bengal, who drew up a map of Hindoostan a century ago, and published in 1788 an explanatory Memoir to accompany it. An appendix on the Ganges and Bramaputra rivers is added. In section VI of the Memoir, and in this Appendix he gives his reasons for dissenting from D'Anville's views regarding the connection of the Sanpo with the Irrawaddy. He was able to add the geographical information derived from the journey of Bógle, and from the itineraries furnished by Giorgi to that given in D'Anville's maps. He attempted to correct the latitude of Lassa as shown in these, by removing it one degree further north ; but later surveys prove the Lamas to have been right, and his conjectures wrong.

His connection of the Mekhong with the Irrawaddy.

92. His hypothesis, for it is no more, that the Sanpo is the head branch of the Bramaputra was founded on the following propositions:—1st, that the Nukiang and the Irrawaddy are identical ; and 2nd, that the Bramaputra from its great size, as seen by himself, required great and far distant drainage grounds. The first proposition he grounds on a fact related in Dalrymples Modern Universal History (Vol. VI P. 205) that four Chinese performed a voyage on the Nukiang-Irrawaddy in the middle of the seventeenth century. His words are (1) :—"They went from Yunan to Yuntchian, and from thence to the frontiers of Ava, where they embarked, and went down the stream to Ava City". He further remarks:—"the river Nukiang, little, if at all inferior to the Ganges, runs to the south, through that angle of Yunan which approaches nearest to Bengal ;" and again "the Noukian is named Irabathy by the people of Ava." In the appendix he says:—"To place it beyond a doubt, that the Sanpo river is not the same with the river of Ava, but that this is the great Noukian of Yunan ; I have in my possession a manuscript draught of the Ava river, to within 150 miles of the place where Du Halde leaves the Nukiang, in its course towards Ava ; together with very authentic information that his river (named Irabathy by the people of Ava) is navigable from the city of Ava into the province of Yunan in China. In a note to this he says, "my information comes from a person who had resided at Ava".

The Nukiang and Irrawaddy connection disproved.

93. This proposition we are enabled to dispose of absolutely. A regular line of large steamers runs now from Rangoon to Bhamo at all seasons of the year. Bhamo is the terminus of the great trade route to China through Yunan. The present writer when attached to Colonel Sladen's exploring party to open up this route after it had been closed by the Panthay-Chinese War had an opportunity of personally examining it. The frontier of Yunan is still exactly where marked on D'Anville's maps, about 30 to 40 miles from Bhamo. In the rains the Taping river is navigable to the foot of hills, within 10 to 15 miles from the frontier, the writer having gone in a large boat to that point in July 1868. The intervening country is occupied by some independent Kachyen tribes, nominally under both Chinese and Burmese influence, but practically beyond control. The real frontier of Ava is thus at the foot of the hills ; and from this point to Ava and to Rangoon the river is navigable ; and the Chinese narrative is literally true (2). And it is also true that the Nukiang approaches within 150 miles of the Irrawaddy in this neighbourhood. But at certain points of its

(1.) Rennell Major, Memoir. p. 216, 217, 277.
(2.) ibid , Memoir. p. 218.

course it is within that distance of the Yang-tse-kiang, of the Mekhong, and of the Sanpo and of the Bramaputra rivers. This contiguity, therefore, of itself establishes no likelihood of connection between the Irrawaddy and the Nukiang. Major Rennell appears also to have held exaggerated notions of the size of the Nukiang. Neither where crossed by the Lassa-Batang road, nor by the Bhamo-Yunan one does it approach the size of the Ganges in its lower parts. And the assurance we have that the survey of the Jesuits of the course of the river actually joined on to the Lamas' survey, and thus brought it down to where we now know it to be the Salween leaves no doubt open on its identity throughout. In any case the *onus* of disproof of the validity of the Jesuits authority is thrown upon those who doubt it, and it is a burden not to be undertaken without serious consideration and a thoroughly complete array of evidence; not a particle of which has ever seen the light or been hinted to exist.

Rennell's conjectures regarding the Bramaputra.

94. The second proposition on which Rennell based his opinions is better founded. He says, (1) speaking of the Bramaputra, "I traced it in 1765, to about 400 miles above the conflux [with the Ganges]; that is as high as the latitude of 26°, longitude 91°, but I was not permitted to go any further." M. Chevalier went higher up and found it navigable between 600 or 700 miles, "but was under a considerable degree of restraint, with respect to making remarks, either on the course of the river or the country." Rennell found the Bramaputra to be rather larger than the Ganges." He measured the Ganges in the dry season, time and place not stated. He found its discharge to be 80,000 cubic feet per second. He estimated its flood discharge to be 405,000 cubic feet. This certainly understates the capacity of the river. There can be no question but that the Ganges and the Bramaputra are both great rivers before they join: and the principal reason Rennell has for considering the Bramaputra to receive the Sanpo is, that its magnitude had evidently been unknown or underestimated by D'Anville. He found its course to be nearly east and west, "and this unexpected discovery soon led to enquiries, which furnished me with an account of its general course to within 100 miles of the place where Du Halde left the Sanpo. I could no longer doubt, that the Bramaputra and the Sanpo were one and the same river, and to this was added the positive assurances of the Assamese. That their river came from the north-west through Bootan mountains." This extract is taken from his paper on the Ganges and Bramaputra rivers, first published in 1781. In his Memoir dated 1788, he restates this and says "These facts together with those respecting the Ava river and the Noukian establish (I think) the strongest presumptive proof possible of the Sanpo and the Bramaputra being one and the same river under different names."

Evidence required before such connection can be rendered credible.

95. This is the whole of Rennell's case. The rejection of his assumptions regarding the Irrawaddy-Nukiang connection does not entirely overthrow the second part of his argument. But it weakens it considerably; as, if it is admitted that the Irrawaddy at Bhamo is as large as the measurements given make it, any arrangement of the rivers chosen must provide a suitable watershed, in analogous conditions to those known to exist in the neighbouring regions, to furnish the flood discharges at that place. So long as the question remains one for reasoning and inference, satisfactory explanations of all the principal known facts must be given. In the absence of such direct proof of the connection between the Sanpo and Bramaputra rivers as a complete survey of their continuous channel would give, several distinct propositions require to be established before it can be satisfactorily settled that they are the same river. These taken in order are:—1st, that the Assam valley and the southern slopes of the Himalayas draining into the Bramaputra are inadequate to supply the volume of water discharged by it; 2nd, that the further volume required is such

(1.) Major Pemberton gives the Chinese route Yungchang to Momien or Teng-ye-chou 4 days, thence frontier 5 days. Momein is west of the Salween; and the additional 5 days would bring the travellers to the navigable part of the Taping river.

as the Sanpo valley from its position, and the probable discharge of the river, is likely to supply; and, 3rd, that a channel be found entering the Bramaputra capable of carrying the volume of water considered, and reasonable grounds furnished for assuming the identity of this with the Sanpo. Further, one of two alternative conditions must be fulfilled, to prove, 1st, that the Irrawaddy has a large watershed to the north of Bhamo, capable of furnishing the quantity of water alleged to pass there; or to prove, 2nd, that the estimates of this quantity at Mandalay, at Bhamo and at the mouth of the Mogoung river are excessively exaggerated, and that no other watershed is required for it than the 30,000 or 40,000 square miles shown in later maps in the Irrawaddy basin to the north of Bhamo.

No such evidence has been offered by Kennell.

96. No evidence of any kind on these points is offered by Major Rennell. His statement that the Sanpo approaches within 120 geographical miles of the Bramaputra is true; but no inference as to their connection can be drawn from this alone. In the absence of specific data to the contrary, however, he advances sufficient grounds to call for an enqury into the alleged identity; but nothing more. And any enquiry which falls short of satisfying the whole of the conditions specified in the last paragraph must be inconclusive.

Attempts to obtain evidence.

97. The jealousy of the native rulers of Assam prevented exploration of the Bramaputra long after Rennell's time. But the expansion of the Burmese empire and its conquest and devastation of Assam, with a threatened advance to Calcutta, brought about a British occupation of the Bramaputra valley to its eastern water-parting. One of the first objects of attention on settling the newly acquired territory was the vexed question of the identity of the Sanpo and Bramaputra rivers. The Government *Gazette* of May 9th 1825 (1) says, "Among the objects of the first interest is the real source of the Bramaputra, which there is reason to think, will require a correction analogous to that made in the origin of the Ganges, and which by cutting off several hundred miles of a singularly and improbably devious course, will be found much nearer to the plains, through which it flows, than has been imagined. The Bramaputra has been identified with the Sanpo, which the Chinese geographers traced through Great Thibet, running from west to east. They lost it on its turn to the south, but the Jesuit missionaries very justly concluded, that it must pass its water into the bay of Bengal. In conformity with this notion M. D'Anville was disposed to think it the same with the river Ava, or the Irrawaddy. He was, probably in the right." This extract represents the first judgment passed on the new evidence then made available.

Researches of Bedford, Wilcox and Burlton. The Bramakoond.

98. To understand this it is necessary to state, that from the point where the Bramaputra enters the plains in E. longitude 96° to Goalpara from 400 to 500 miles lower down, near where it finally turns to the south, only three of its branches, the Bramakoond branch, the united Dihong-Dibong, and the Subansiri can have any claims to be the Sanpo. Attention was first exclusively directed to the exploration of the Bramakoond branch, which contains the sacred spring giving the name to the river. The exploration of this showed at once that it could not be the Sanpo, and it is to the results of that exploration that the editor of the *Gazette* refers. Subsequent researches have entirely corroborated the first impression as to this branch. These will first be noticed, and the further steps of the investigation be then given. Lieutenant Burlton had been deputed to examine the Bramakoond and he learned that it was a comparatively small stream. Lieutenant Neufville learned that beyond the sacred well, the Bramaputra was a "mere mountain rivulet." Dr. Griffith visited the

(1) Wilson H. H. Prof. Documents illustrative of the Burmese War 1827.

Koond on October 22nd 1836. He found the stream (1) fifty yards wide, the total breadth of the bed being one hundred yards, much occupied by boulders and rocks *in situ*, "The water mark of floods visible on some of the rocks, is probably eight feet above that of this time of the year. "The water was supplied by two distinct streams" the bed of one forms the second defile, this is very insignificant. The other occupies the course of the bay, and can only be seen from a low station in the sand beneath. It is a small waterfall" This description is confirmed by Mr. Cooper who visited the place in 1870, and who saw it debouching "from the hills in a noisy turbulent stream, and turning sharp from the north flow quietly eastwards."

The north eastern tributaries of the Bramapootra.

99. The failure with the Bramakoond branch, which had been proved incapable of carrying the Sanpo, and the criticisms of the *Gazette*, appear to have led to a more thorough exploration of the remaining branches of the Bramaputra from the north. Capt Bedford, Lieut. Wilcox and Lieut. Burlton were engaged during the dry season of 1825-26, in a detailed examination of the whole of the secondary feeders of the Bramaputra. From time to time letters descriptive of the progress made appeared in the *Gazette*, were republished by Professer Wilson in his work, and were used by Wilcox in compiling a complete memoir on a "Survey of Assam and the neighbouring countries executed in 1825, 6, 7, 8." He also published a map of this region. The memoir has lately been republished with other papers relating to the Hill Tracts between Assam and Burmah (2). This contains all the principal facts of the exploration made. The map shows the Dihong entering the Bramaputra eight or ten miles below the town of Sudiya, and 20 or 30 below where the Bramakoond branch reaches the plains. A mile or two up the Dihong, the Dibong joins it on its left bank. It is shown with a channel of the same size as the Dihong's; but it comes from the north-east, while the latter has a course from the north-west. Fifty or sixty miles up this course it is joined by a stream called the lesser Dihong; the greater channel being connected to the Sanpo. One hundred or so miles lower down the main channel the Subansiri flows into the Bramaputra. No other large tributary enters the Bramaputra from the north until the Bomash joins it opposite Goalpara. The southern watershed of the Assam valley is bounded by the ridge of the Khasya hills which run westward as a spur from the Aracan Yoma. Several rivers carry the drainage from the northern slopes of these hills to the Bramaputra; the most easterly, the Noa Dihing, entering it above Sudiya; and the Buri Dihing, the next one, enters 80 miles below Sudiya.

Bedford's journey up the Dihong.

100. The first journey was made by Captain Bedford up the Dihong on 18th November 1825. "On the first day after leaving the Bramaputra, Captain Bedford was struck with the placid and mild character of the river, expecting as he did, from all accounts of the utter impossibility of navigating it, to find it abounding in rocks and with a violent current. Sands were as frequent as on the Bramaputra... 19th November. The second day no material obstacle was encountered; however stone beds were found to be taking the place of sands, and several rapids were passed...20th November. The third day the rapids were more numerous, and more troublesome, but on the fourth (21st) they obstructed progress materially." No other information than this is given by Captain Bedford regarding the Dihong.

His examination the Dibong.

101. He examined the Dibong in December. "On the 4th December Captain Bedford entered the mouth of the Dibong. He found the water beautifully clear, running in a bottom of sand and stones." "As he went up he found the difficulties from rapids increase." On the afternoon of the 12th the river presented three

(1) Griffith Dr. Journals p, 26.
(2) Selection of papers regarding the Hill Tracts between Assam and Burma, 1873.

branches, two of which were found impracticable. In order to enter the third, which appeared to be the main stream, it was necessary to clear away a number of large blocks of stone, and employ all hands to force each boat singly over the rapids. On the 14th December the width of the river was reduced to between twenty and thirty yards, and as it was not above knee deep it appeared not unlikely to be near the head of this branch. "This last days experience removes the Dibong as well as the Bramakoond branch from the list of claimants for the passage of the Sanpo.

Wilcox on the Dihong.

102. Lieutenant Wilcox himself explored the Dihong. The date is not given. He says (P. 16). "To Captain Bedford's account of the Dihong I can add little, but as the mode of travelling has not been clearly explained I shall endeavour to describe it." He went with canoes capable of carrying 10 men each. The forces were combined to drag the boats over the rapids. In 1826 again he went further up the river than Bedford had done; Lieutenant Burlton accompanying him. They travelled overland; and went a short distance beyond the mouth of the Shiko, a rivulet entering on the left bank in latitude 28° 5′. In one place they found the breadth of the river to be 200 yards, but from one to two hundred yards would be added to the bed when the river was full. "The river is generally calm and gliding with an easy current". In another place, "the breadth of the river was reduced at this point to one hundred yards, and it was still mild and tranquil but the form of the hills gives rise to the expectation of immense depth." In a note to this he says "The question immediately occurs why we did not take a section of the river; we had not the means, and the utility of providing them was not so obvious *then*. But we had taken note of any petty rivulet joining the Dihong from its mouth upwards, and were perfectly aware that none of them contributed sensibly to the quantity of water. Whatever the discharge of the Dihong at its mouth, we had here the same quantity nearly—the entire river. A very simple calculation shows us that, for the undiminished discharge of fifty thousand cubic feet per second, and supposed velocity of only three miles, the depth required is only thirty seven feet. Mr. Klaproth's objection to the size of the river appears then not well founded."

Statement of its Discharge.

103. The amount of fifty thousand feet referred to is mentioned in an earlier part of the memoir. Answering the criticisms in the Gazette he says, that Lieutenant Burlton measured the Bramaputra below the Buri-Dihong mouth, and also near Sudiya. At the former place he found the discharge to be 86,727 cubic feet and of the branch passing Sudiya 32,413 cubic feet. He states that a rise had taken place before the latter measurement was taken.

Wilcox on the Subansiri.

104. Before discussing the above figures, the further data relating to the Subansiri and to the Bramaputra will be given. The former is contained in the following extracts. Wilcox says (P. 8), "having arrived at its (Subansiri's) mouth on the 28th November, I commenced my survey on the following day, but I was disappointed to find my further progress impeded on the sixth day by rapids, occasioned by the accumulation of round stones brought down from the hills, where from its mouth, I had got but twenty two miles latitude to the north...The Abor Miris could only tell him "of the Subansiri that it is divided above into three branches. It is called by them Kamla and the principal branch rises in the northwest ...The Subansiri is scarcely inferior to the Ganges at Allahabad in December. I found the discharge at its mouth 16,000 cubic feet per second, and up to the hills its tributary streams are few and of little consequence. I think there is no doubt of its being the Omchu of Du Halde and Rennell." No further information whatever is given in the memoir of a specific kind regarding the Bramaputra or its upper northern tributaries. Captain Pemberton in his Report on the eastern Frontier of British India gives an extract from an appendix to Wilcox's memoir (1)

(1.) Wilcox Captain. Asiatic Researches, Vol. 17.

concerning the Bramaputra. Immediately below Gobati, hills confine the Bramaputra to the breadth of one thousand two hundred yards, the narrowest in its course through Assam; there in the rainy season boats have to be moored till a westerly breeze springs up of force sufficient to carry them through the narrow strait; but there is often great difficulty in passing up even where the river flows in an open bed.

Mr. C. Markham's testimony that these researches are the sole ones on the Sanpo-Bramaputra connection.

105. It is upon the data contained in these extracts that geographers have concluded that the Bramaputra is the continuation of the river of Great Thibet. Mr. Markham records the series of surveys made on the northeast frontier, and gives a list of the whole of the authorities available, in manuscript or otherwise. He says (1) "Captain Bedford and Lieutenants Wilcox and Burlton were sent to explore the Bramaputra towards its source in 1825..... To this day no explorer has succeeded in adding, in any appreciable degree, to the knowledge conveyed by the discoveries of Bedford and Wilcox, as regards the region beyond our northeast frontier, and towards the sources of the head waters of the Bramaputra and Irrawaddy." No mention is made of any later researches or publications of the discoveries than those above indicated, so that we have here the whole, absolutely the whole, of the evidence which has outweighed the testimony of the Thibetan and Chinese geographers, and D'Anville's maps to the connection of the Sanpo with the Irrawaddy.

Insufficiency of the evidence produced.

106. At first sight it is clear that this evidence fulfils none of the conditions which should be insisted on as indispensable to establish a claim for the entry of the Sanpo to the Bramaputra. There is no discussion of the various watersheds, and no reference to flood discharges, or means given for estimating them. The exact or approximate widths of the various streams in the plains where the section was tolerably regular, with the rise from low to high water, which are the first elements in the calculation, are totally neglected. The widths in the hills, without any indication of the rise and fall or velocity of the stream, leaves all to conjecture. If the low water discharges of the main river and its various tributaries were all taken at the same time, with the whole of the varying conditions of the atmosphere and surroundings in a settled state, a direct comparison might be made with approximately correct results between the discharges and drainage areas. From the descriptions given it seems that the hills to the south and the mountains to the north are covered with later geological formations of the same date; and the dry weather discharge is in a great measure made up of subsurface drainage slowly flowing away. But it is known that showers of rain fall through a great part of the cold season in Assam and the Himalayas to the north of it; and these last are covered with snow likely to melt suddenly even in winter, and certain to yield from time to time accessions of water to the streams. There is thus introduced a number of disturbing elements into any such calculation; and the effects of these are considerably enhanced when any measurements made are not taken simultaneously, and still more when there is nothing to show at what particular time each was made. Thus no date is given for Burlton's gauging of the Bramaputra below the Buri Dihing, nor for that at Sudiya. We know that on most Indian rivers the discharge varies from flood to low water from 40 to 1 and 50 to 1, and at intermediate stages it ranges within these ratios. A discharge of 86,727 cubic feet per second in the Upper Bramaputra in February would be large, in November or December it would be comparatively small.

Wilcox's errors in estimating the discharge of the Dibong.

107. Wilcox appears, however, to consider it a very large discharge; and deducting the measured discharge at Sudiya of 32,413 cubic feet, assumes that the remainder, over 54,314 cubic feet, is the contribution from the Dihong alone, and that this quantity was still in the channel at the highest point reached

(1.) Markham Mr. C., Memoir of the Indian Surveys 1871, p. p. 83, 84.

by him in the hills, where the width of the river, apparently both in dry season and in flood, owing to the form of the hills, was restricted to 100 yards and its current was mild and tranquil. He calculates that thirty-seven feet in depth with a velocity of three miles, would enable the river to carry this quantity. With regard to this it is to be noted, that from his description of the river here,—a narrow reach bounded by smooth perpendicular rock, with a rapid at each end of the rock—it seems probable that this was one of the pools met with in rocky mountain rivers, comparatively deep, and with a gentle surface flow. It is improbable that this flow extended to the whole depth of the pool, as the bar forming the lower rapid would hold back all the subsurface water and his whole description is quite incompatible with a flow 37 feet deep at a mean rate of nearly 4½ feet per second. His purpose in bringing this statement forward is to answer Klaproth's objection to the Dihong being the Sanpo, based on the small size of the river. This objection he says "appears then not well founded."

His neglect of proper precautions in the Survey.

108. As the principal purpose of these surveys was to support Rennell's hypothesis, and furnish answers to the criticisms of Klaproth and others who maintained D'Anville's views, it is not easy to understand how the necessity of making exact measurements of the rivers escaped them. Their object doubtless was to try and survey the river channels to points within the Thibetan frontier, where they could have been assured of the identity or non-identity of the Sanpo with the Assam river; but a few days experience proved that the physical difficulties of the journey, and the opposition of the Hill Tribes called Abors made this task then impossible. These difficulties were known in Wilcox's case beforehand, as his attempt followed Bedford's on the Dihong. It would have been by no means difficult to have determined the size and the discharge of the river, pretty nearly, in that reach. There was a small canoe which they had there. They had watches and could have noted the velocity of the current. A mean velocity of 4½ feet per second implies a central surface one of over six feet, and the words "mild and tranquil" are not applicable to that velocity in a mountain stream. A string and a stone could have given the depth. As it is, the calculation given is misleading; and, even admitting it to be correct, would tend to show that the Dihong cannot be the Sanpo.

Inferences from figures and map given by Wilcox.

109. The Bramaputra at Sudiya drains, by Wilcox's map, nearly 7,000 square miles by its Bramakund and Noa Dihing branches. Between Sudiya and where it was measured below the mouth of the Buri Dihing over 6,000 additional miles are drained into the Bramaputra through the Buri Dihing and smaller streams, excluding the Dihong. The country is very similar throughout; and, in the dry weather, in the absence of disturbing causes, the *pro rata* discharge must be similar from all the streams. So that it is reasonable to expect that the quantity added by this area would be to that above Sudiya as 6 to 7. A rise of the river at Sudiya before it was gauged must be allowed for. Say it had 28,000 cubic feet when the lower section was taken. Then 24,000 cubic feet must be deducted from the total discharge of the Bramaputra below the Buri Dihing, in addition to the quantity passing Sudiya to find the probable quantity coming from the Dihong-Dibong. That is, instead of over 50,000 cubic feet there would be less than 35,000 coming from these united rivers according to the gauging. The Dibong itself cannot be neglected in its contribution. By Wilcox's map it drains over 2,500 miles of precisely similar ground to that of the Dihong on the west, and of the Bramakund on the east. Its discharge cannot have been less than 10,000 cubic feet; thus reducing the amount for the Dihong to 25,000 cubic feet per second instead of over 50,000. Wilcox learned from the Hill Abors that the Dihong was formed of two large branches, one from the east, the other from the west. He shows the former, conjecturally, on the map. It must add to the quantity by which the Dihong's discharge is lessened; but conjectures are futile. And notwithstanding Wilcox's statement that none of the petty rivulets joining the Dihong had contributed

sensibly to the volume of the river it is certain that all of them together must do so, and at the rate of 4 feet per second for each square mile of country. The watershed between the Bramaputra and the Thibetan boundary is considerable to the north of the river, and occupies at the very least 4,000 to 6,000 square miles in the basin of the western Dihong. Is it fair to assume that this area, partly snow covered, and exposed to the winds which sweep at all seasons of the year up the southern slopes of the Himalayas—would give a less drainage per square mile than the less exposed portions of the river basins below? If not, then the 4,000 square miles which the Dihong cannot help draining in its upper water shed fully accounts for its discharge, both as arrived at by calculation and as seen by Wilcox. It is more than likely that its basin is more extended than this; but so far as the figures furnished to us go, we are bound to conclude from them that the whole of the discharge measured by Burlton in the Bramaputra was contributed by its Assamese basin, and that no far distant additional areas are required to account for an unexplained balance.

Mr. Cooper's evidence on the Dihong and Bramaputra.

110. The late Mr. Cooper has added some information to the above respecting the Upper Bramaputra and its tributaries. He tried to cross from Assam to China in 1869, but got little further than the Bramakund, where two Missionaries had been murdered in the interval between Dr. Griffith's visit and his own. He found that 18 hours rain on the 28th September raised the Bramaputra at Sudiya twelve feet, to highest flood level; a proof of the supply coming from contiguous drainage grounds. He ascended the Dihong for a few miles in the plains by boat at high flood. He found the river about a quarter of a mile wide at its narrowest part, and flowing with a deep swift current. No precise data for the depth or velocity of the stream are given. As before remarked for the Sanpo, it is known that rivers in mountainous countries, or flowing in plains with steep slopes, have comparatively shallow beds. Visitors to Switzerland, Styria and the Tyrol or to the rivers from the Himalayas where they debouch into the plains can recall this marked characteristic. The Upper Bramaputra and its tributaries are situated in these conditions, and have all comparatively wide and shallow beds. A total rise of 25 feet from low to high water is probably the utmost the Dihong reaches. Taking this, with the quarter mile width and a high flood velocity of 7·5 feet per second we have its highest flood discharge of about 250,000 cubic feet per second. We have before found that the Sanpo probably discharges more than 750,000 cubic feet per second at high flood. It does not require much reasoning to show that the Dihong cannot carry the Sanpo.

Failures to establish alleged channel of connection between the Sanpo and Bramaputra.

111. A conviction that this is indeed the case has been gradually forcing itself upon the persons most qualified to form an opinion on the subject. The ablest officers of the survey department, who have been for some years engaged on the north eastern frontier, have of late come to the conclusion that the Subansiri has better claims than the Dihong to be the Sanpo; though the two latter rivers are still represented as connected on the map, and some writers assert that the connection is established. The testimony of the surveyors must have much weight as to the comparative claims of these rivers; as the whole of their courses within British territory and for some distance within the belt of steeply sloping mountain occupied by the Hill Abors is now included in the completed field of operations; and sufficient opportunities have been afforded to permit a thorough knowledge of their relative capacities to be obtained. Major Godwin-Austin, in a paper read before the British Association in 1877, advocated the Subansiri as having superior claims to the Dihong. Major General Thuillier, late Surveyor General of India, states (1) "that the volume of water passing down the Subansiri is said to favor the idea of its junction with the Sanpo, and further careful observations are now being made by Lieutenants Harman and Woodthrope, R. E. to ascertain whether the Subansiri exceeds the

(1). Proceedings Asiatic Society of Bengal 1878, p. 27.

capacity of the Dihong, or of the Dibong, the former of which has long been held by English geographers to be the real outlet for the Sanpo into the Bramaputra near Sudiya... *The question however was altogether conjectural at present,* and must remain so until more conclusive evidence is produced as to the real course of the Dibong as well as of the Subansiri upwards, or other Native explorers can penetrate downwards from Lassa to the head of the Assam valley through the Abor and Miri tribes inhabiting that remarkably unknown and untrodden region."

Information obtained by the Abbe Desgodins.

112. General Thuillier's remarks appear to render it probable that the survey officers consider that the Dibong has claims which may be resuscitated for the honor of carrying the Sanpo; and it is curious to find that the remarks were called forth on a letter by the Abbé Desgodins, the author of the annals of the Thibetan Missions, dated 28th March 1877, wherein he advocates the Bramakund branch as the most suitable. He had received information from an old Lama regarding the Sanpo, which "after a certain course through the Llopar country falls perpendicularly from the top of a rock into a valley the name of which he did not know. The height of the fall is so great that it makes one giddy...Every one in Assam knows the fall of the Bramakund, whither the heathen resort as pilgrims. M. Bernard has often spoken to me of it as a fall remarkable for its height, the force of its volume of water, and the hollow it scoops out in falling. The southerly position attributed by my confrère to this vast fall, and the northly position given to it yesterday by the Lamas, induce me to believe that the fall at Bramakund must be precisely the fall of the Yar-kin-tsang-po (Sanpo) which then becomes the Bramaputra, the latter being navigable almost immediately after this addition."

Four Bramaputra influents claiming to be the Sanpo.

113. There are thus four Sanpos in the field of conjecture; having claims of the same kind with each other to be the true one. The three highest tributaries have already been considered. Wilcox measured the Subansiri in December 1825, and found it then discharged 16,000 cubic feet per second. It is not possible to compare this amount with those given for the Bramaputra at Sudiya and below, as the month in which these were measured is not given. But *primâ facie* the quantity carried is extremely small for what is now the principal Assamese claimant for the Sanpo; since it is known that it has a considerable watershed of its own in the Himalayan slopes; and the amount is less than half that drained from the 7,000 square miles of the Bramakund branch We know also from Nain Singh's statement that the Sanpo about that season carries nearly 30,000 cubic feet per second, which is not likely to be diminished in its downward progress.

Inprobability of any one of these influents being the Sanpo.

114. It may be inferred, with the highest degree of probability, that if the Subansiri and the Dihong, not to mention the Dibong and the Bramakund, have equal claims to carry the Sanpo, neither of them has any claim whatever to do so. Colonel Yule states (1) that Wilcox deduced from measurements of the Dihong and of the united Bramaputra at Goalpara, that, after deduction of the former as foreign supply, there remain a low water discharge of 90,188 cubic feet per second as the discharge of 15·3 square degrees of surface. A square degree in these latitudes is about 4,250 square miles. This makes the watershed of the Bramaputra to the east of Goalpara, a town near the great turn of the river towards the south, about 65,000 square miles, excluding the problematic Sanpo basin. It is near this point that Wilcox states the river to be about 1,200 yards wide. Recalling what is said above concerning the steepness of slope of the Upper Bramaputra we should expect it to have a moderate rise from low to high water. The Irrawaddy at Mandalay has a rise of less than 30 feet; at Myanoung of about 40 feet. It is probable the Bramaputra

(1). Yule Col. Mission to Ava p. 359.

between Goalpara and Gowhutty does not rise beyond the former figure. Enquiries made from Captains of steamers navigating that river confirm this estimate. Assigning to its highest flood a mean velocity of 7·5 feet, the greatest ever known on the Irrawaddy, we have with a rise of 30 feet a highest flood discharge of about 800,000 cubic feet; and with a 40 feet rise at this place an extreme discharge of less than 1,100,000 cubic feet per second. Now if Nain Singh's account, confirmed as it is by that of Bogle, and that of Manning be correct, it is highly improbable that the extreme flood discharge of the Sanpo can be less than 750,000 cubic feet per second where he saw it. It is thus clear, that if the figures above given be even approximately correct, it is quite impossible that there can be two or more tributaries of the Bramaputra discharging into it volumes of water equal to each other, and to that of the Sanpo, in addition to a flood discharge from a watershed of 65,000 square miles of one of the rainiest regions in the world.

Inconclusive state of the subject.

115. In the preceeding paragraphs every item of information known to throw light on the question of the identity of these rivers, so far as figures can show it, has been gathered together, and presented in a form enabling each person to draw inferences for himself. The writer, in the conclusions he has drawn, has used simple hydrological principles of undisputed trustworthiness; and, while these, applied to the figures furnished, lead inevitably to the deduction that there is no connection between the Sanpo and the Bramaputra; and that the Sanpo and the Irrawaddy are continuous; it is to be noted that the whole of the figures and the consequent inferences are too vague and unprecise to be accepted as finally settling the question. It is to be regretted that so long a time has been allowed to elapse, since opportunities were made available for measuring the main channels and tributaries of the Upper Bramaputra and Irrawaddy, without complete and accurate measurements of their capacities being taken. Those now in progress on the Bramaputra, will be of the highest value; but should be supplemented by corresponding ones on the Irrawaddy by competent observers. It is possible that this would give a satisfactory solution in a hydrographic point of view; while the geographical question can only be solved by an actual survey of the whole course of the rivers.

Wilcox's researches as to the sources of the Irrawaddy.

116. Wilcox contributed further evidence of other kinds on the arrangement of these river basins and watersheds. He appears in all his journeys and surveys to have taken the testimony of the natives on the Sanpo-Irrawaddy connection; and he further undertook a journey himself to discover the sources of the Irrawaddy. Taking his enquries in the order of the distance from the Irrawaddy, we find that on ascending the Subansiri he met some people of the Miri Tribes from the hilly district of the Dihong and Dibong. He says "The Miris did not pretend to any certain knowledge of the origin of the Dihong, and they seemed to think notions current among their tribe and the Assamese as little worthy my attention. They informed us that a tradition prevails with the Abors of the Subansiri that their hunters once travelling in quest of game, went much further towards the north than usual, and that they arrived at the banks of a noble and rapid river separating their wild hills from cultivated spreading plains, whence the lowing of oxen was distinctly audible. Another singular account they mentioned of the Dihong Abors that the Dihong is an anastomosing branch of a river of great magnitude, called Sri Lohit, which also throws off the Bramaputra and passes into unknown regions to the eastward. The Abors are supposed to see this Sri Lohit, and on the opposite bank numbers of people of a strange tribe are perceived coming down to the ghat to bathe but it is too rapid and too broad to be crossed." The word Abor is a term applied to the mountaineers from distant parts, meaning strangers, and has come to be used in Assam as a generic term for the more savage and independent of the hill tribes. These Subansiri Abors appear to hold the higher parts of the river, and prevent the passage of others through their territory. They themselves are

not great travellers, as the other mountaineers and equally exclude strangers. If intercourse were general through Thibet or farther through Assam, they could easily learn all about the Sri Lohit, which is their name for the Irrawaddy in Burma. But they are not allowed to travel freely in Thibet, and they do not travel much through Assam, and still more rarely through the highland tribes and independent Khamtis separating the Assam from the Burma valley. It seems difficult then to account for them even knowing the name Sri Lohit of a river, whose nearest point, if it does not pass through Great Thibet, is 300 or 400 miles off; and still more to account for them calling an insignificant stream a noble and rapid river—a river of great magnitude—of which they esteemed the Dihong and Bramakund small branches. They lived on the Subansiri; but do not compare even it with the river to the north. It is probable that the Abors would have the run of the narrow belt of country occupied by kindred tribes, lying between their own lands and Thibet. We know that the Sanpo is one and a half miles wide about 60 or 100 miles to the north of them; and that there is nothing improbable in the story about the hunters seeing this river, though the anastomosing part of the story may not be entitled to credit. As it stands, the testimony is most remarkable.

Testimony of the Hill Tribes.

117. The Abors or Bor Abors, from the upper parts of the Dihong, could not or would not give Wilcox any information about its sources; and would not permit him to ascend. He, however, obtained some from another source. He says:—"I have now to present the information derived from the Lamas by Muli, a Mishmee Chief of the Dibong, with whom I had long been acquainted by name as the most influential man of the Dibong mountains. He says Nushipu Lama told him that the Lamas call the Dihong, Lassa Chombo (Tsongbo he also pronounced it). There are two branches, one from or passing Lassa, and the other, the smaller of the two, rising near the heads of the Bramaputra. Below Lassa is a town called Kongbong, and the river also goes by that name. The Khama Debàs country is at the source of the above mentioned eastern branch. The Lassa people, on their way to Lassa valley; go up the lesser Dihong and cross over snowy mountains from its sources to those of the Bramaputra. They occupy one month from Lassa. They do not mention any other river nearer than three months journey.....I must add that this information was not given in answer to leading questions." To understand the force of this evidence it must be remembered that Wilcox shows the lesser Dihong as coming from the east apparently round the heads of both the Dibong and Bramakund branches of the Bramaputra. It is thus according to his own showing the extreme north-easterly tributary of the Assam river, and if the Lamas go up the Lesser Dihong to cross over from its head waters to the Lassa valley or the valley of the Sanpo, they do so at a point beyond all the larger influents of the Bramaputra, and where it must be physically impossible that the Sanpo can subsequently be connected with that river. Possibly there is a misprint in the portion extracted; but the statement is curiously confirmed by another witness cited by Wilcox. He was an old Assamese, who had been captured by the hill men when young and sold in Thibet as a slave. The fact was well known, and his subsequent escape. He spoke Thibetan. He had resided with a Lama and his wife at the village Aprawa, at the source of the Bramaputra, in the east, beyond the Mishmee country. He had repeatedly been on trading excursions to the Khama Deb country, distant ten days journey over snowy mountains the whole way. Then he says, on descending from the height, the sources of two rivers were found, one running to the west which he was informed was the Dihong and the other to the south.

Wilcox allows himself to be undecided.

118. No other definite information could be obtained from the tribes on the Dihong itself; the Abors knowledge being limited to the fact that it was not navigable, and came from a long distance. Wilcox had made plans to return to the head waters of the Bramaputra, but could not carry them out. He says "I

have regretted it ever since, as of all my plans it appeared the best calculated to assure success. Certain knowledge would at least have been obtained from the Lamas whether the Sanpo continues beyond the source of the Bramaputra." He more than once reverts to the idea of gathering information from the Lamas themselves regarding the Sanpo, and its alleged continuation beyond the Bramaputra. This would be satisfactory evidence if it would be obtained. Intercourse of an extensive kind takes place between the hill tribes and the Thibetan beyond, and numerous products are exchanged; though no through passage is permitted to individuals in these parts. The Lama country certainly exists to the north and east of the Bramaputra; and if the Lamas there live near the Sanpo it cannot be the former river.

He learns the existence of a large eastern branch of the Irrawaddy.

119. While staying at Sudiya, preparing for his expedition to the Irrawaddy he found numerous visitors from the upper tracts of this river, including Burmans, Shans, Khamtis and Chinese. He says "It may be supposed that I did not neglect to take advantage of these opportunities to investigate as fully as I was able the probability of any connexion of the Irrawaddy with the Sanpo but though the existence of a large eastern branch of the former river, hitherto unknown was proved, there appeared every reason to conlude, both from the information of these various tribes, and from the want of magnitude of the branches of the Irrawaddy, that the Sanpo could not possibly have its exit to the ocean by this channel." The existence of the large eastern channel has since been confirmed by Colonel Hannay's enquiries; by maps given by Burmese at Bhamo to the writer; and by Mr. Strettell's visit to Muntgoung where this channel leaves the hills in latitude 25° N.

Wilcox and Burlton travel to the head waters of the Irrawaddy feeders.

120. Previous to the time when Wilcox made these researches it would seem from the remarks quoted of the Editor of the *Government Gazette* in 1825, that Rennell's hypothesis of the debouching of the Sanpo through Assam had been accepted in India without examination or evidence of any kind. Rennell certainly gives none. Since 1825, all the authority for this same belief centres in Wilcox and his testimony. It is therefore necessary not to neglect any of it, however tedious it may be to go over the whole ground. The journey to the Irrawaddy valley must thus be considered and discussed. He, in company with Lieut. Burlton, and a party of followers, left Assam by the valley of the Noa-Dihing, the highest tributary on the left bank of the Bramaputra, in April and May 1826. On the 4th May they left the Dihing valley, and got into the hills above 2,000 feet high. Here they were tortured by the "dumdum," a kind of sand-fly, which harassed the whole party, causing inveterate sores. Next day two men were attacked by fever. Water ran short; but it rained all night. They slept at an elevation of 8,429 feet above the sea. They marched on these mountain crests for a few days. The people were suffering very severely from fevers and swollen legs. It rained a good deal; and the weather was cold at nights. The ground was of gneiss and clay slate. Snowy mountains could be seen to the north; and some snow lay on their path. When they reached the top of the dividing range they were saluted with a violent storm of hail, thunder and lightning; the latter setting fire to one of the fir trees opposite. The ground was the most villainous they ever saw. It was a sodden mass of rotten leaves and moss, and thick fern. The road had been described as a dreadful one, generally entailing loss of life. A skull was picked up confirmatory of this. Two of Lieut. Burlton's men lay down and refused to come on. They were brothers. One stayed to assist the other. To help them was impossible. *They halted on the Phungan river, near the course of which they had descended from its sources, but it was of considerable size when they saw it.* It continued to rain. They wished to halt for a day to recruit; but their rice ran out. Leeches now joined the sand flies as torments. In half an hour, thirtyone of the former were torn from one leg. Another of Burlton's men broke down, and stayed be-

hind. They continued to descend; crossing a hill of sienite. Rain and fogs and mists; tree and prickly bamboo jungle; fine tall nettles in luxuriant abundance, with mud ankle deep added to their annoyances. The jungle grew denser, so that they had to cut the way. They had to march on the edges of stream; sometimes on boulders, sometimes in the water. The leeches got worse. Every six or eight hundred paces a fresh collection of thrity or forty might be plucked off the ankles. Burlton took fever, several of the Singphos got sick. One of the two brothers turned up; the other, and the third man left behind, were dead. About ten at night the river suddenly rose three or four feet, and subsided again as quickly.

Examination of a mountain stream.

121. They were met by two Khamtis of rank on the 16th May, having reached the inhabited country. Some cultivation was now observable. They recruited for a day in a village and went on on the 20th. It continued to rain heavily. About two o'clock they "beheld at a distance the object of our deepest interest—the Irrawaddy winding in a large plain." They stayed as the guests of the Raja, who received them hospitably. He wished to use them against a neighbour with whom he had differences. The Raja "spoke of the system of warfare and mutual aggression which has endured for the last fifty years without either side having gained a material advantage. He lamented it, but saw no prospect of its termination." The geographical knowledge of the Khamties was very restricted. The Lukiang, or other Chinese river is not known. With the Lama country there was no immediate intercourse; traffic being carried on through the Mishmees. Wilcox was lame, and Burlton had not recovered from his illness. They desired to examine the Irrawaddy; but a good deal of uneasiness and opposition was manifested. At length their wish was gratified. Ponies were furnished and they rode to it. "The Irrawaddy we were surprised to find but a small river, smaller even than we anticipated, *though aware of the proximity of its sources.* It was not more than eighty yards broad and still fordable, though considerably swollen by the melting snow...*As to the origin of the Irrawaddy, I felt perfectly satisfied from the moment I made enquiries at Sudiya;* but since further evidence, founded on the report of the natives, might not have satisfied those who had adopted Mr. Klaproth's opinion, that the waters of the Sanpo find an outlet through the channel of the Irrawaddy, I had resolved if possible to have ocular and incontrovertible demonstration; and I could not help exulting, when standing on the edge of the clear stream, at the successful result of our toils and fatigues." The height was about 1855 feet.

The results of these researches of Wilcox and Burlton.

122. Both Wilcox and Burlton merit the highest praise for their energy and devotion in the whole of their attempts to solve the problems before them. At very great personal sacrifice and risk they tested each tributary of the Bramaputra in succession; and finished their work by this visit to the Irrawaddy valley. But it does not appear that they had the training and skill requisite to deal successfully with such tasks; nor did they possess the comprehensive grasp or practical tact which might have availed them in the absence of those qualifications. In not a single case have they given sufficient facts to enable exact inferences to be drawn. The sizes and rise and fall of the water in the streams were not given. In many cases no gaugings for discharge were taken. When they were, the mode and attendant circumstances were not noted. And the inferences drawn by themselves are, on their own showing, entirely fallacious. If the native testimony they gathered has any value at all it is quite fatal to the Sanpo-Bramaputra theory. And what are we to say to the above quoted testimony as to the Irrawaddy?

Conditions of research unfavorable.

123. Firstly:—It is evident that Wilcox was prejudiced entirely against the claims of the Irrawaddy before he started from Sudiya. The grounds for this prejudice are not detailed, but appear to be the smallness alleged for the upper branches of the river; though

he is the first to bring to notice the large eastern branch of the river. He received confirmation of the existence of this in the Khamti country. He does not notice it any further; or discuss the possibility of its being the Sanpo channel. His conclusions were formed before he commenced the investigation. Secondly:—the whole party were so knocked up by their sufferings that when in the Khamti village they were unfit to prosecute further enquires. It was with much difficulty they got back to Assam. And thirdly:—the evidence they gathered is inconclusive. The river visited by them flows into the Irrawaddy; but there is nothing to show that it was one of the principal branches. One of the streams they passed down from its head had acquired a considerable size in one or two days march. It was raining heavily and continuously; and a stream eighty yards wide and two or three feet deep such as they saw, must have had a very small gathering ground. The geographical ignorance of the Khamtis in the vicinity, fully accounted for by the permanent state of hostility with their neighbours, prevented any definite information as to the river they were on from being obtained. So far as the narrative shows, the identity of the river is on purely conjectural grounds. It is then of no higher value than that resting on the examinations made of the tributaries of the Bramaputra; and the testimony of the Abors and Miris; and where these are not adverse to Wilcox's view, as on the whole they are, they are absolutely neutral on the points at issue.

Difficulties of prosecuting researches.

124. That more favorable results have not attended the attempts at exploration is in great measure due to the anarchy prevailing over the whole of the Upper Irrawaddy region, and throughout the belt of highlands on the southern slopes of the eastern Himalayas. Repeated efforts have been made by missionaries, surveyors and other travellers to penetrate to Thibet from Assam; and valuable lives have been lost; but the want of cohesion amongst the various tribes, and the chronic state of warfare amongst themselves have raised insuperable obstacles to success. The mountains of the Irrawaddy basin above Mandalay and the whole valley above Bhamo are in a similar or rather increasing condition of anarchy. The Panthay rebellion in Yunan has permanently weakened the Chinese influence over the border tribes. Burmese authority has been continually waning before the successive and successful inroads of the Kachyens, who are allied to the Abors. At present that authority is lower than ever before known above Bhamo. In 1867, the Governor of Bhamo was entangled in the jungle and killed with a large body of followers. Colonel Sladen's expedition was repeatedly fired upon in 1868, and some of the Panthay escort killed by Chinese. Mr. Strettell relates that his boat was fired upon above the Thsnbo defile; and that the late Mr. Graham whom he met near the same place was attacked, and killed three men in return. The incidents attending Colonel Browne's mission to Yunan when the whole party was attacked, and Mr. Margary murdered are too recent to need detailing. These countries lie wholly without the range of British influence and the difficulties arise rather from the peculiar present conditions of the neighbouring governments than from any evil disposition in the peoples. The whole of these hill tribes are more or less a mixture of the pure yellow race of man, most likely from the Thibetan plateau, with the darker skinned tribes of the plains of India or allied tribes. The Ghoorkhas, the Bhotanese, the Kachyens and the Karens, show distinct signs of connection with the yellow race in their squat and muscular forms, round faces and heads, and square shoulders. At the same time there are traces equally distinct of their connection with the more dusky races of the plains. They have differences from both types, and resemblances amongst themselves, though the mixtures may be different, and their speech is widely so. The Burmese, Shans, Siamese, and Assamese are almost purely of the yellow race; possessing great powers of organization; a considerable degree of civilization; and a highly philosophical religion in common. The mixed tribes mentioned have, except in the Nepalese and Bhotan valleys, where the yellow increment seems to predominate, little power of organization; as even when they possess plain lands in common they rarely get be-

yond village communities at warfare with each other. Their civilization is of a much lower type throughout than that of their neighbours of purer race. Their religion through the whole extent of the mountain regions where they are found is a degraded spirit,— or rather demon-worship, never rising higher than the propitiation of evil powers. But with all this, they are amenable to kindly dealings, are hospitable, and sociable. The writer was brought in contact with the Kachyens on Colonel Sladen's mission. He slept in their houses and shared in some of their ceremonies; and though some were mischievously inclined, it was only a few individuals out of a large number. It is probable that with more favorable conditions the whole of these would become as useful members of a state as the Karens of British Burma are at present where they are inoffensive agriculturalists of industrious and inaggressive habits.

Further hydrographic data necessary.

125. Until these obstacles to a successful survey of the continuous river channel from the Sanpo to the sea are overcome we must rely on purely hyrographical considerations. So far as these have been brought forward, they leave the matter in a somewhat inconclusive state. This might be improved by perfectly accurate data for the Bramaputra and its principal tributaries; and also by others for the Irrawaddy at and above Bhamo. The Bramaputra is at present being completely surveyed under the directions of Colonel Walker, Surveyor General of India, and the results will shortly be known. If a survey could be made of the Sanpo downwards, a final decision could be obtained. Failing this a full survey of a portion of the Irrawaddy at Bhamo, with the establishment and record of gauge readings there for a flood season with occasional gaugings of discharge would be of the highest value; especially if accompanied by measurement of the river towards and above Muntgoung. This last is necessary with a view to supplement the surveys on the Bramaputra.

Geological notes of Wilcox and Griffith.

126. The geological notes of the survey parties of 1825 and 1826 are of interest; as they show that the Aracan Yoma where it leaves the Himalayas, is of much the same character as the outer flanks of these throughout their length bordering the north of Hindoostan. A nucleous of granitoid gneiss is covered with deposits of sandstones, shales and coal measures. In the bed of the Noa Dihing they found a coal seam cropping up. Petroleum springs and mud volcanoes existed in the neighbourhood. Dr. Griffith who passed over much the same ground in 1836 records that similar coal seams and petroleum wells were passed. The former were of good quality, the latter oozing out in considerable quantities from springs, isolated and in groups. No other minerals were met with by the party. These coal measures are found at various points of the outer Himalayas; and lower down the Aracan Yoma both in the Irrawaddy valley and on the Aracan side. No traces of the noble metals are to be found in the whole lengh of this line, from the Sawalik Mountains to Cape Negrais, nor in the range of ocean islands continuous with this. An apparent exception to this law will be pointed out in describing the Kyindwin valley. The fact of this continuity, as well as the corresponding one of the richly endowed mountain ranges of the northern Himalayas and their continuations, seems to favor the argument that the Aracan Yoma is a prolongation of the Himalaya Proper; which it could not be if it is cut through by the Sanpo; and joined to the Northern range. This strengthens the case for the Sanpo Irrawaddy connection.

PART II.

The Hydrology of the Irrawaddy River.

INTRODUCTION

1. When the hydrographical relations of the different regions of the Irrawaddy valley have been examined, the hydrology of the main river and of its affluents and minor basins requires to be considered. That is, the boundaries, areas and relative positions of the gathering grounds having been approximately determined, it is further necessary to learn in what manner and under what conditions the supply of rainfall reaches the various areas; how the quantity of water precipitated is distributed, whether at once thrown into the main channel or stored up to be discharged slowly, or held back to be altogether re-evaporated and pass away without affecting the river discharge. The various agencies concerned in the supply and in the distribution are enumerated and passed in review, so far as material permits, in this second Part of the Report; and the results so manifested at the head of the delta are described in some detail.

SECTION I.

The Summer Monsoon and the Irrawaddy Floods.

Difficulties in the meteorology of the subject.

2. The meteorological conditions of the Irrawaddy valley not only partake the difficulties inseparable from the geographical questions; but possess a considerable share of their own. With the exception of the stations of Prome and Thayetmyo in the lower part of Burma, no continuous sets of instrumental observations have been recorded at any point for the whole of the Irrawaddy basin; whether this is taken as restricted to the Burmese valley; or as extended to that of the Sanpo of Thibet. And though useful information of a general kind is available, there are differences amongst meteorologists as to the principles on which the prevailing monsoon winds, on which depend the rainfall of the valley, are to be explained. The one view holds that the monsoons are identical with the trade winds, or rather are extensions of them. The other view is that the monsoons, though arising from the same causes that produce the trades, have separate and local existence, on a more or less extensive scale.

Explanation of the trade winds.

3. Very eminent meteorologists like Dove, Herschell, Maury, Marie-Davy etc. class the monsoons of India with the trade winds; and all accept Hadley's explanation of these as correct. The sun heats a belt of the earth's surface in its daily revolution; that part lying vertically under it receiving the greater heat. The atmosphere over this belt also receives a great portion of the heat; probably from 20 to 50 per cent. of that of the rays passing through it on their way to the earth. Of the remainder, if it falls on the ocean a part is expended in warming the water and producing sea currents; and a part in evaporating it, the vapour and the heat contained in it being absorbed by the atmosphere. When the surface heated is land, this absorbs the heat to an inconsiderable depth by day, and gives it out at night. The air immediately over it ultimately receives the whole of the heat, with small exceptions. As the air is heated it expands and becoming lighter than the surrounding colder air, which presses inwards, ascends. The colder air flows in and on being warmed in its turn follows the former in a continuous current. The belt of the globe heated by the sun's rays extends to a considerable distance on both sides of the line immediately under the zenith; but the heat decreases generally with the distance from it. The air passes over this surface from both sides in more or less horizontal layers, gradually getting warmed till it reaches the position of greatest heat, when it ascends. The currents of air from both sides towards this heat equator are called the trade winds. In the upper part of the air a converse course obtains. The heated air attains a greater elevation than the cooler on both sides of it, and its ascensional flow in a single stream to the upper regions is followed by a division into two currents flowing away from the heated belt towards the poles. These upper currents, in a reverse direction to the trades, are called the anti-trades. A section of the atmosphere would show the movement of the trades and anti-trades as a continuous one throughout. At a certain distance from the heat equator the character of the movement changes. A great portion of the upper current has been cooled down, and returned with the lower one to be again heated. The volumes of both streams of atmosphere are considerably lessened, the lower one being too small in amount to carry the upper one, and the two flow side by side in opposite directions. These streams of air, having a general direction to and from the poles, have been called the polar and anti-polar winds.

Cause of deviation of the trade from a true north and south direction.

4. If the sun's course were continually over the earth's equator the heat equator and belt of ascensional currents would be generally coincident with this. But it moves yearly from 23° S. latitude to 23° N. latitude; and both the heat girdle and the trade winds follow the sun's path. And the distribution of sea and land affects the position of the belt. The predominance of land in the northern hemisphere draws the heat girdle somewhat to the north of the equa-

torial circle. The revolution of the earth on its axis deviates the trade winds and polar currents from the meridian direction in their passage to and from the heat equator. The circles drawn on a geographical globe at the different latitudes are seen to diminish in size from the equator, where they have the largest diameter, to the poles, where they become nothing. The surface of the earth thus moves with a greater rate of velocity on approaching the equator from the poles; and the winds taking his course are deviated from a true north and south direction. That approaching from the north takes a north-easterly direction; that blowing towards the heat girdle from the south has a south-easterly one. The existence of these winds has been fully demonstrated by experience throughout the tropical and subtropical regions; and the explanations given are generally accepted as the true ones. Differences arise as to the extent of the motion north and south of the earth's equator of what is called the *ascension girdle*, or *belt of calms;* and as to how far the prolongations of the trade winds and the monsoons are due to general causes, and to causes entirely local; using the word cause here in the restricted sense of intermediate agent; the sun's heat and the earth's motion being understood as primary causes about which there is no doubt.

Different views as to the monsoon winds.

5. The meteorologists who follow the above named consider that the motive power of the trade winds, the belt of the maximum heat, oscillates through the range of the tropics following the course of the sun; and they also in general consider the monsoons to be prolongations or extensions of the trade winds. Herschell (1) says the monsoons of India are due to the disturbing action of the land on the trade winds. "In the Atlantic Ocean the equatorial limit of the north east trade shifts with the season from 5° 15′ to 11° N. latitude, and that of the south from about 2° to 3° 15′ N., so that the medial line lies always a little north of the equator. In the Indian seas, however, and especially in the vicinity of the great Asiatic Continent, the disturbing influence of the land is most clearly exhibited, issuing in a complete reversal of the north-east trade during a considerable portion of the year in one, and the other half in the contrary direction. When the sun is south of the equinoctial, it being the cold season in those continental regions, the regular trade winds prevail throughout those seas, and what is called the north-east monsoon is in fact no other than the undisturbed north-east trade wind. But when the sun has north latitude, and especially about the northern solstice, it is vertical over a very large region of Arabia, Hindoostan, Bengal, Burma, and Cochin, which become, of course, intensely heated. Under these circumstances, besides the permanent line of maximum temperature in the equatorial sea, there is developed another more intense and less regular line of the same nature, under or near the northern tropic, towards which and not towards the equator, a large proportion of the intermediate air is drawn. Receiving thence a northen impulse, and that impulse carrying it into a region of less rotatory velocity than that which it has left, it assumes a relative south-west direction, and is called the south-west monsoon."

Herschell's explanation of the monsoon.

6. M. Marie-Davy coincides with this view (2). He says:—"In the Indian Ocean, transversely limited to the north by Asia, the maximum of heat is transported from winter to summer, to latitudes very distant one from the other: the zone of calms runs in the direction of the meridian an extent at least as great, which produces the monsoon." Elsewhere he says the zone of calms moves from 10° S. to 10° N. "At the surface of the great ocean the maximum of temperature is displaced slowly in the course of the year; but in the Indian Ocean the position of the Asian continent and above all of the high plateau of Himalayan mountains is a cause of grave perturbation. The south of Asia is highly heated during summer; the southern slopes of the chain participate in

Marie-Davy's views on the monsoon.

(1). Herschell, Sir John. Meteorology 1861, p. 61.
(2). Marie-Davy, M. Meteorologie Generale, 1877, p. 197, &c.

this temperature and favor the formation of ascending currents. The resulting aspiration commences by counter balancing the ascending layer at the surface of the ocean, and finishes by absorbing it....The summits of the Himalayan mountains elevate themselves to such a height that they are covered with perpetual snow, but their grand masses and the high plateau of Thibet, are, during summer, at a higher temperature than that of the layer of air situated at the same level over the Indian Ocean. The N. E. trades which tend to be established over Asia are greatly paralysed by the action of these high projections. It is easy to understand that the S. E. trade wind, having passed the equator, and been transformed into south or south-west can penetrate very far into the land beyond. It is carried by its own velocity, and by the draw of the air sliding up the southern slopes of the chain; it is not balanced by opposing winds as at the surface of the great oceans; and it thus passes much beyond its natural limit, towards the north....The region of minimum pressure shown by the barometer is not found at the zone of maximum temperature as usual near the surface of the sea, it is carried to the north of the high plateau of Thibet and extends to the latitudes of Burnaul in Russian Asia."

The influence of the Thibetan plateau on the monsoon.

7. These statements add some details to the general explanation of Herschell. Both mention a line of heat or aspiration zone separate from that of the tropical girdle of maximum heat which is the origin of the true trade wind. M. Marie Davy localizes this on the southern slopes of the Himalayas, and on the Thibetan plateau, which from their great height and the thinner layer of air to intercept the heat, receive a greater amount from the sun than the lower land. As the mean level of the plateau is about 3 miles, and its mountains 4 to 5 miles above the sea, a height far above that of the thickness of the ordinary trade wind, an ascensional current is produced in the higher regions of the atmosphere with a consequent much greater depth of the monsoon current in approaching those high lands. He mentions that a region of minimum barometric pressure is found as far north as the latitude 53° or far beyond the northern bounds of the plateau. The point of minimum pressure is that to which the air invariably flows, so that the monsoon winds overshoot the position of their motive power, if that power is to be found only in the plateau .M. Marie Davy explains this by saying that the monsoon winds acquire a velocity, and thus a stored-up force, which in the absence of opposing currents carries them far beyond the source of their movement.

Distinction between monsoons and ordinary trade winds.

8. It is this peculiarity of the monsoon winds which distinguishes them from the ordinary trade winds, that is, the over passing the limits of the sun's course to the tropic of Cancer in 23½° N. latitude, and appearing as S. W. winds in the region where a N. E. wind might be expected to blow. Professor Dove (1) holds that there is nothing extraordinary in this; that so far from the monsoon being an abnormal development or modification of the trade winds, these should be called imperfect monsoons. His explanation of the movement is as follows:—The barometric pressure is found at a minimum at the zone of greatest heat towards which both monsoons and trade winds blow.

Professor Dove's views.

The pressure of the atmosphere shown by the quicksilver consists of two parts:—that due to the pressure of the air in its dry state, and that due to the moisture mixed with it. When the temperature increases the air increases in volume and ascends, thus lessening the pressure. At the same time its power of retaining moisture, or the vapour elasticity increases, and when this can freely evaporate from water the sun's heat is employed in doing this, and the pressure tends to increase. There is thus a double process in action, and the results are not

(1.) Dove, Professor, H. W. Das Gesetz der Sturme, 1866, p. 29, &c.

always readily discernible. It is known from observation that the elasticity of the vapour in the air increases in the hotter zone, with the increase of temperature. It is most marked in the region of the Indian monsoons from the cold to the hotter months; and particularly towards its northern boundaries. He gives a table showing the elasticity of the vapour in Paris lines for the following stations all of which are in or near this monsoon region, for each month in the year. The yearly averages alone are here given :—

Table I.

Ajausk	1·83
Pekin	3·45
Nagasaki	5·30
Hongkong	8·17
Nertschinsk	1·84
Burnaul	2·15
Tomsk	2·32
Bogoolowsk	1·89
Slatonst	2·12
Catherinenburg	2·08
Orenburg	2·53
Derbust	4·29
Baker	4·55
Lentoran	4·82
Alexandropol	2·37
Alagir	3·30
Tiflis	3·39
Kutais	3·34
Redutkale	4·39
Rainsk	4·49
Calcutta	2·31
Bombay	9·09
Madras	8·95
Trevandrum	9·11
Amboina	9·04
Palembung	9·54
Brutenzorg	9·61
Banjoewangie	8·34
	10·08

This table shows that all the southern and sea coast stations have a very high vapour elasticity throughout the year relatively to the northern inland ones. Dove also gives a table for a larger number of stations for the whole of the eastern hemisphere, showing the atmospheric pressure due to the dry air. A third table gives the resulting pressure due to both, that indicated by the barometer. From the whole of these tables it is proved that the barometric pressure follows that of the dry air over the Asian continent, and thus reaches a minimum in July. From this arises a force or tendency causing the winds to blow from all quarters towards the region of minimum pressure. Measuring this force by Parisian lines on the mercurial barometer, the region where it has the greatest effect in the northern hemisphere in July is marked by a boundary denoting four of these lines of an oval shape in Asia running from the Aral sea through Burnaul, Pekin, Shanghai, and to the north of Calcutta and Benares, and including Turkestan, Gobi, part of China and the plateau of Thibet. All within this boundary is the region of wind attraction and ascension *(Auflöckerungs Gebiete)* of greatest intensity, above four lines. Without it is a zone concentric with the former where the force ranges from two to four barometric lines. This stretches from the eastern Ural mountains to Japan, and includes Northern Arabia, Persia, the Indus and Ganges valleys, Northern Burma and South China. The boundary where this force ceases in mid ocean is unknown, but to the west it passes between Asia and Africa, and through the Black Sea and St. Petersburgh. Probably a similar region is found in Africa. All the desert countries lie in the region where the force is strongest. The minimum atmospheric pressure does not agree directly with the distribution of heat from the sun, as the temperature in July diminishes from Arabia towards Central Asia where, nevertheless, the pressure is least. The dampness of the air accounts for the result.

The region of air in draught and ascension.

9. Thus, in spring the wind blows from Siberia towards India, but the sun's action is very powerful in the northern region and by heating the air diminishes and weakens the flow. In Burnaul from January to May the vapour elasticity does not reach 2 lines, while in Calcutta it is 4, and the barometer here falls only 4 lines, while in Burnaul it falls 5; and by June the respective falls are $7\frac{1}{2}$ and $5\frac{1}{2}$ respectively. The lowest pressure is thus found north of the hottest zone, and the summer monsoon reaches far beyond this region. The

Influence of the Thibetan plateau on the S. W. monsoon.

S. W. monsoon loses a great part of its vapour against the southern flanks of the highland of Central Asia, and thus cannot supply the vacancy. Dove expressly states that the monsoon winds are in no wise flowings of cold air to warmer regions analogous to the daily seawinds common to some coasts.

Dr. Adolph Mühry's views on the trade winds, and on the monsoon.

10. Views widely different from the foregoing are put forth by Dr. Adolph Mühry in his General Geographical system of the Winds (1). He lays down as first principles that all great winds arise from aspirations or drawings in front, and not from pressure behind. The aspiration is due to the solar action on the earth, or insolation; the heat acquired by the land being transferred to the lower layers of the air, which expand and ascend, causing a vacuum into which the colder air is drawn. A lower barometric pressure always marks this region. He gives the origin of the trade winds in the belt of calms; but from an examination of all available evidence concludes that this belt does not oscillate, as alleged, following the course of the sun; but remains between the latitudes of 3° S. to 5° N. The monsoons are homologous with the common daily sea winds; and may rightly be called yearly sea winds. "They arise from partial and local aspiration centres, following in the region of the trade winds, and having a certain constant continuance. They are thus to be defined as *smaller aspiration winds i. e., detractions of the lower layers of the general aspiration air streams, lying to the side of the aspiration region.* They arise when a continent of great extent, in the region of the trades, is heated through insolation to a higher degree than the sea, thus causing a stronger ascensional stream, which acts as an aspiration.

His divergencies of opinion from the before quoted writers.

11. He takes up one by one most of the statements by Herschell, Dove, &c., referred to above, and explicitly contradicts them. Thus, the S. W. monsoon is not as Halley thought a descent of the upper anti-trade to displace the N. E. trade. The calm belt does not oscillate on the globe to follow the sun's course from south to north through several degrees of latitude. The S. W. monsoon is not a continuation of the S. E monsoon from the southern hemisphere, with its direction changed by the earth's rotation. It is homologous with a coast wind, and may be called a yearly sea wind. This monsoon has a smaller vertical depth than the trade wind. Its direction follows that of the coasts and valleys of India and Burma. It does not extend beyond Asia; and its direction in the south east of Asia is changed from S. W. to S. and S. E. It is a mistake to suppose its aspiration region is in Central Asia, in consequence of a great region of atmospheric ascension there (*Auflöckerungs Gebiete;* with a reference to Dove); for no calm air sea is known in Central Asia. The middle girdle of Asia is less heated than the southern coasts where a heat centre of 26 R. (F. 90°) is found in July. And a lower barometer stand is found in the Indian Ocean than on the continent.

The principal facts of the monsoon are known with some exactness.

12. There is thus apparently an entire contradiction between the views held as to the principles regulating the machinery of the monsoon. But as occasionally happens with instruments in familiar use, like the steam engine, the injector, etc., a complete knowledge of their details is accompanied by considerable perfection in their use, while the principles are in dispute, the contradictions found here may be useful in presenting the facts in clearer light, if only the facts themselves can be ascertained and verified with sufficient exactness. About some of these there can be little doubt remaining. Considering the summer monsoon of Southern Asia as a whole, it is a steady rain-bearing wind blowing for nearly half the year from equatorial oceanic regions extending from the east coast of Africa to the east coast of China, and more or less converging to a region in Central Asia. It takes the place of the N. E. trade wind as this is

(1.) Mühry D'Adolph. Das allgemeine geographische System der Winde 1869.

found in the northern open oceans. It is joined on to, and is in continuation with the S. E. trade of the southern hemisphere, when this has overpassed the equator; and resembles in its principal features the form this would take if it were constrained to go to the far north. A focus of heat, or wind origin, from whatever cause arising, separate from that of the ordinary trade, whose source is always within the tropics, exists in the sub tropical, or temperate zone, within the four line limit defined by Professor Dove. Whether that focus is an extensive area, a fixed point, or series of points, or whether it itself moves about and gives rise to variations in the monsoon, bringing with them flood or drought, or famine or plenty to the countries of south-eastern and central Asia, are questions still to be determined. Our knowledge is very imperfect on these heads ; but it seems probable that all these countries within the monsoon area are inextricably bound up together in a subjection to common laws regulating the monsoon distribution over this area. The famine and drought years in India appear to have been accompanied by famine and drought in northern China. The years 1873 to 1877 shows this. In 1877 the summer monsoon took an undue development early in the season in northern and western India. It then swerved over to the east ; and the whole of S. E. Asia from Assam to South China with Further India received for the rest of the season an excessive rainfall, while N. W. India and China suffered from too little.

13. One of the latest writers, Wojeikof (1), who treats on this subject at length, gives a detailed description of the phenomena of the monsoons. As it is only the rain-bearing summer monsoon we have to deal with here ,a concise account of it can be taken from him. The monsoons of Hindostan, Further India, and China are closely analogous, and arise from the same cause, the expansion and indrawing of the air, through the sun's heat, and the great insolation of a portion of the Asiatic Continent. The rain from the summer monsoon commences in Ceylon and Cape Comorin in April, in Bombay in June. The greatest rainfall in Southern India is in May and June ; in Bombay in June and July ; in Calcutta, and generally to the north-east of the Bay of Bengal in July and August. The southern parts have another increased rainfall in October. In Saigon and the southern parts of Further India, a double maximum of rainfall, at the begining and end of the monsoon, occur. North of this, from 35° to 50° ,a single maximum is found in July and August. The cause of these phenomena is, that in spring the increasing temperature commences to warm the continent, and the regions of lowest pressure are found one in China, the other in Central India. Inflows of saturated air precipitate their rainfall near their origin and centre of action. As the sun moves northward from May to July, each heat focus moves towards the interior of the continent, to beyond the Himalayas, probably to the southernmost part of the Desert of Gobi near 40°, as the high mountains and plateau hinder the heating and expansion of the air. The richly laden rain-bearing winds trend in the same direction. The heaviest rainfall in the world is found to the north of the Bay of Bengal, beyond the Tropic of Cancer. Towards autumn the heat foci return south drawing with them the wind centres of India and south-east Asia, and bringing a second maximum of rain.

Wojeikof's account of the progress of the summer monsoon.

14. The political exclusiveness of Thibet is to be regretted not only on account of the important geograpical problems it causes to remain unsolved but for the total negation it entails of the instrumental observation of its inner countries. Although there is a general admission by the writers above quoted that the centre of origin of the whole monsoon movement in July lies concentric with Dove's zones, and is thus nearly coincident with the Thibetan plateau, none has mentioned it as probably the most important factor in the circulation of the monsoon winds. M. Marie-Davy indeed suggests the southern slopes of the

The importance of the Thibetan plateau as a central factor in the summer monsoon

(1.) Wojeikof A. Die Atmosphärische Circulation, 1874.

Himalayas, that is, the outer flanks of the plateau, as the heat centre, but recognizes that the winds go beyond these. He ascribes some influence to the plateau. Herr Wojeikof places the centre to the north of the plateau, and expressly excludes this from assisting the operation in any way. He considers the high ranges as a hindrance to the general circulation. The plateau fares somewhat better at the hands of the latest writer on the monsoons, Mr. Blanford (1), who, as meteorological Reportor to the Government of India, has submitted yearly reports for 1875 and 1876 on the data of the Peninsula. In these and in his paper on the winds of northern India, and in his *Vade Mecum* he mentions the Himalayas and the plateau as a disturbing factor in the monsoon system. He shows clearly that the summer monsoon wind is divided into two great streams by the Indian Peninsula, the one coming from the Arabian sea and flowing over India to the Punjab and more southern skirts of the Himalayas; where it is met by the other current which traverses the Bay of Bengal in a S. W. direction, impinges against the great circular front of the plateau, and is deflected towards the west and north; causing small storms and cyclones with the first current. He points out that the "Himalaya is an impassable barrier to any interchange of air currents between India and Central Asia in the lower half of the atmosphere; but not to that loftiest stream which in the winter months, sweeps over the snowy range, clothing them with the long feathery banners, which may be seen streaming away to the north east from such giants as Kinchinjunga and its attendant peaks. Observations are, indeed, yet wanting for the lofty tableland which lies beyond in the path of the current, but it is hard to believe that so deep and steady a flow of air serves no other purpose than to feed the gentle out-flow of the north-east monsoon of southern Asia."

It is a permanent monsoon centre independent of the general circulation of the atmosphere.

15. He elsewhere quotes Hooker, Strachey, Schlagentweit, Shaw and others to prove "that amid all the local irregularities due to the varying directiion of the valleys, the prevalent winds are southerly up to the principal range and that day winds of great force, attributed by General Strachey to the heating of the elevated plains, blow in the same direction through the passes. Only in Turkestan does the prevalent wind appear to be northerly up to the Mustagh or Karakorum range." The southerly and south-westerly winds thus blow from the ocean to the great plateau all the year round, even when the north-west monsoon prevails in the plains to the south. From the north it appears that northerly winds converge to the same point. If data were obtainable for the whole northerly front of the plateau in Gobi and Mongolia during winter, and the prevalence of this northerly wind were established, it would prove that the plateau itself is a great permanent centre of atmospheric elevation and attraction throughout the year. Huc mentions the bitter cold winds, certainly from the north, which predominated when he first entered the desert table land to the north of the plateau in November and December. A few days of warmer air on the high Tantla Mountain was possibly due to a change from the south. Prejevalsky relates that in the same part and at the same season 23rd November to 10th February intense cold and continued gales often prevented their hunting. He does not give the direction of the wind, but its excess of coldness proves it to have been an anti-polar stream. If then, the plateau is so energetic as a heat and wind focus when all the conditions are against it in the coldest seasons; it must predominate over the whole of the neighbouring regions in the time of the summer monsoon, when the insolation of the high plains and mountain masses, which is known to be as great as at lower elevations, operates solely on the upper layers of the atmosphere, and by its concentrated action produces an increased vertical flow. It is probable that the local centres of heat of China and India approach and finally coalesce with the permanent centre in the mid-monsoon, and thus bring the monsoon to its greatest intensity. As the peninsula of Further India is a large and important mass, it is *prima-facie* probable that a third partial heat centre moves over it to and from the plateau with the season.

(1.) Blanford, H. F. Reports on the meteorology of India 1875 and 1876. Winds of northern India 1873. Indian meteorologists Vade-Mecum 1877.

16. Though no instrumental observations of rainfall are available for the Thibetan plateau, the great rivers issuing from its inner and outer drainage systems are natural indicators of the highest value regarding its hydrometrical condition. At present we have only general information as to the majority of these rivers ; but there is a singular agreement in the testimony about the floods, however widely different the testimony may be in its origin as to time and place. Huc (1) mentions that the Hoang Ho was in extreme high flood where he crossed it in its upper part in the summer of 1845. Mr. Ney Elias (2) in an account of his survey of the same river describes the floods as coming from the plateau at the height of the monsoon season. Mr. Oxenham (3) records that the level of the Yang-tse-kiang is in winter much below the plains ; but in summer it rises above a great portion of them. The great floods of this river appear usually in July or August. They are derived not only from the Thibetan highlands, but from the different river systems of its vast basin. Alternations of rainfall in these somewhat interfere with the regularity of the rise and fall in the main channel ; and when spread over the whole valley intensify or prolong the effects. But the periodicity of the ordinary floods identify them as proceeding from the summer monsoon whose action is common to the whole plateau. General MacLeod (4) in his Journal of his visit to Kiang Hung in 1837 notes that in March the Mekhong was at its low water stage ; but that it rose and spread out with the monsoon. Lieutenant Garnier (5) records that very close to the same place at Seimlap, latitude 21°, the river attained its maximum on 19th July 1867, light steady winds blowing from the S. W. Lower down at Bassac, the river feels the influence of the moving heat centre. Its floods at Bassac in latitude 14° 54′ attained its maximum on 20th September 1876, after continuous heavy rains. The wind had been from S. E., but changed then to N. E. The river was in flood earlier in the monsoon. In its upper part, latitude 25°, where crossed by the Bhamo-Yunan road, it is known to follow the variations of the monsoon, though no data can be given for its highest rise. The Salween is closely identical with the Irrawaddy in the oscillations of its floods, as far as its course is known. No records have been kept of its variations. The Irrawaddy has been gauged since 1869 in the delta only. The results are given in detail and plotted in the diagrams. From these it is apparent that the highest flood rise is almost invariably in August. It would be a great boon if the presence of British Agents at Mandalay and Bhamo, with their attendant staff could be made of use to furnish data regarding the river in those parts. At Bhamo this would be of the highest value for many reasons. It is not known whether any records are kept for the Bramaputra or its principal influents. It is, however, well known that these follow the monsoon changes, and acquire their greatest intensity of flood usually in August. The Ganges and Jumna rivers have been recorded at different points for many years. Some of these records have been collected and published by General Fraser, R. E. All available data prove a close relation between the floods of these and the other great rivers from Thibet. Gaugings of the Indus, and of some of the five large rivers flowing to it from the Himalayas, have been published in a scattered form in the Roorkee Papers and separate memoirs. From the few records at disposal it appears the August floods predominate over those of other months ; with occasional exceptions. Generally speaking, they appear regulated by the same laws as the more easterly rivers enumerated. Major Herbert Wood, R. E. (6) gives valuable information regarding the Amu Darya (Oxus), which takes its source in the mountains to the north west of the plateau. He states that this river rises with the melting of the snows in the latter part of spring ; and attains its greatest flood with the maximum summer heat. He gives a diagram of the fluctuations of level of the water from 23rd June to 10th

The value of the great rivers of the plateau as indicators of its meteorological condition.

(1) Huc St. Abbi.
(2.) Elias. Mr. Ney. J. R. G. S. 1870. On the Hoang Ho or Yellow River.
(3.) Oxenham, Mr. E. L. On the Inundation of the Yangtse-Kiang. J. R. G. S. 1875.
(4.) McLeod General. Mission to the Frontiers of China, 1836-37. Parliamentary Papers 1869.
(5.) Garnier Lieutenant F. Voyage d'Exploration en Indo-Chine 1873.
(6) Wood, Major Herbert, R. E. Notes on the Lower Amu Darya etc.in 1874. R. G. S. J. 1875.

September 1874, which shows that a high flood took place on 10th July; but the maximum height was reached on 3rd August; when its discharge at Toyaboyin was 142,800 cubic feet per second. Colonel Gordon (1) describes some of the upper streams of the same river; and notes that the waters were rising in May 1873. Captain Kostenko (2) records that the Russian expedition found the same streams in flood in the summer of 1876. The rivers on the western part of the northern front of the plateau are described by Dr. Scully (3). He states that the principal rivers of Eastern Turkestan, the Khutan Yarkand, Kashgar and Aksu rivers, unite to form the Tarine river which afterwards receives the Kucha and Kaider and flows north-eastward to Lake Lob. "Those streams in their passage across this tract, mostly flow in wide channels between low banks of sand...The volume of their streams varies according to the season. Thus in winter, even the largest of them are so much shrunk as to be crossed dry-footed by stepping from stone to stone...In summer, on the contrary, they are all so much swollen by the melting snows, that they fill the whole of these wide channels; and as in the case of the Yarkand river, form a stream nearly a mile broad and only passable by boat."

The desirability of recording regularly and systematically all information about these rivers.

17. If it be allowable to suppose the spring melting of the snows supplemented with mid-summer rains, we have a close resemblance in the phenomena of the whole of these rivers floods which can only be due to an identity in the cause, that is, the summer monsoon action on the great Thibetan plateau. The observations of the Pundit Nain Singh prove that the rivers of the Lake Region, such as the Shyal Chu, and others, are in flood in summer, from June to August. He states that the Sanpo is flooded from April to June; but the statement is on hearsay, and the time is, in all probability, extended later through the season. If we had a complete record of the whole of the rivers enumerated, with all their fluctuations for a long period of years, probably more would be done to obtain an insight into the periodic floods and famines of India and China than any other information would give. There has been a tendency of late years to ascribe a cycle of famine and drought years to the prevalence or absence of sun spots as these recur in undecennial periods. The years of minimum sun spot are for the present century those whose last two figures are divisible by 11, such as 1833-77 etc. A large amount of data, mostly thermometric and raingauge records have been gathered and studied with a view to elucidate this question. Mr. Blanford in a separate paper, and in his Vade-Mecum gives some results of this study to the present time. Sir W. Herschell and Professor Wolf have shown from old records that years of abundant sun spots appear to be more fruitful than others. Messrs. Meldrum and Lockyer assert that the quantity of rain that falls on the globe appears to vary with the abundance of the sun spots; the greatest rainfall occuring about the period of sun spot maximum, and *vice versa*; the variation not exceeding 15 per cent. on the whole. The connection alleged between the sun spots and the rainfall is, that the increased numbers of sun spots indicate greater energy in the suns' atmosphere, whereby it radiates a larger amount of heat to the earth's surface. This causes a stronger evaporation from the ocean, and a consequent increased precipitation on the land. So far as the thermometer and raingauge registers given show, the assertion is sustained; but only in a slight degree (4). There is on an average, a higher temperature recorded, and a somewhat larger rainfall, in the years of maximum sun spot than in the minimum ones. But the distribution of raingauges and thermometers over the earth's surface is so unequal and scattered that it is difficult to deduce a general law valid for the whole globe from these records. And the exclusive use of such instruments tends, from their small size and uneven distribution, to a particularization and exaggeration of local or secular peculiarities. If used in combination with records of another kind, that is with those

(1.) Gordon Colonel T. E., R. E. The watershed of Central Asia. R. G. S. J. 1876.
(2.) Kostenko, Captain. The Russian Expedition to the Altai and Panin in 1876. R. G. S. J. 1877.
(3.) Scully, Dr. J. Meteorology and climate of Yarkand and Kashgar. Indian meteorological memoirs 1876.
(4.) Blanford H. F. Report on the meteorology of India in 1876.

having a tendency to average and generalize results, possibly deductions of higher value would be obtained. Such records are available in the diagrams published by the United States Government (1) yearly, showing the levels of the great American Lakes Ontario, Erie, Michigan and Huron, from the year 1859 to date. These lakes equalize all partial irregularities of rainfall over an immense area of ground, and serve as better indicators of general laws of rainfall for that part of the world than all the raingauges available. Similar records exist for the principal rivers and lakes of Europe. The Swiss Government (2) publishes regularly admirable diagrams of rainfall and variations of river and lake level for all the hydrographic systems of that country. Herr Grebenau (3) gives the records of the Rhine at Strassbourg for the greater part of a century. The Dutch Government (4) issue a yearly report showing all oscillations of the rivers there. Eminent hydrographers like Lombardini, Cialdietc. supplement by their studies the publications of the Italian Government regarding the lakes and rivers of Italy. The name of Belgrand (5) heads the list of numerous contributors to hydrological science in France. And isolated students like Bornneman Harlacher &c render possible comparative studies of German rivers. The discharge of the Thames for many years is given in Parliamentary Reports. If a tolerably complete collection of such data were made, and plotted on a uniform scale for comparison, any general changes affecting the rainfall of Europe as a whole would be more readily discernible than from the collation of raingauge records alone. And if the records of the whole of the rivers within the authority of the Government of India were in a similar manner rendered accessible for comparison with those of Europe and America, one of the most important steps to deduce a history of the past or current atmospheric changes of the whole globe affecting the production of the soil and welfare of the people would be made. And no attempts to foretell, or to prepare for such changes in the future, can be of much avail, until considerable progress is made in such comparative hydrography.

The want of such information renders impossible any analysis of the greater phenomena of the monsoons.

18. It is with a view to urging on high authority the extreme desireability of gathering and placing on record in an easily accessible and convenient form for reference any information of the kind under discussion now available in India; and of procuring it from other sources, if possible, for comparison, and with a view to elucidate questions like those relating to the Irrawaddy Floods, and even more important ones, that the present section is written. The want of such information has become manifest in the present enquiry and the means in progress for gathering or recording such facts as will save for future enquiries appear to the writer to be inadequate for useful ends in that direction. Much waste of time has been caused by turning from reference to reference as new phases of the problem developed; and much disappointment has been felt as the most promising fields for useful facts, and for interpretation of facts, turned out incomplete on the more important points. It is quite impossible at present to offer or to obtain such a connected series of facts as will serve as safe ground on which to form general conclusions even as to past or current events, much less predict future ones, related to the causes on which the floods depend. But it is possible to show where the data are now wanting; and present failures may lead to better results in other hands if the weakness shown is in some measure remedied. An examination of the data now available, and a few suggestions as to these considered desirable, appear the best thing that can be offered just now.

The Meteorological data for Burma are very defective.

19. If we take firstly the meteorological observations at present instituted in Burma; they are wholly insufficient. The records of these published in the Local Government Gazette were extracted at length for two or three years; but were found deficient in many respects. The gaps were filled after some months

(1.) Report of Chief of Engineers 1875-77.
(2.) Schwiezerische Hydrometric Beobachtungen, 1874 etc.
(3.) Grebenau, H. Den Rhein and Mosel for 1807 bis 1872.
(4.) Veslag aan den Koning 1875-76.
(5.) Belgrand M. La Seine 1873.

delay by the Rangoon Meteorological Office. It was then found on reference to the Meteorological Reporter to the Government of India, Mr. Blandford, that the Burmese records were considered too imperfect to use for comparison with the Indian ones. The barometers had not been tested, nor the various instruments compared, and arranged on the same plan. And though for rainfall and possibly wind direction the records may be useful, they were all, with one exception, the station of Akyab, rejected for consideration in the first Meteorological Report for India for 1875. Two other stations, Rangoon and Moulmein, have since been included in the general scheme, and their observations have been utilized in the Report, lately issued for 1876. These three Burmese stations are all on, or close to, the sea cost; and can thus give no indication of the phenomena of the interior of the country or of the Irrawaddy valley. The inclusion of the other principal stations of Lower Burma, together with, at the least, Mandalay and Bhamo in Upper Burma within the sphere of observations, is necessary to the solution of the most restricted local problems; and this indispensable extension has great claims on the attention of the Government.

The Meteorological Reports for India.

20. The Meteorological Report for India is an admirable scientific work, containing only the most trustworthy observations and indubitable results. The exclusion of all that does not attain to these standards elevates what is done to the highest class of work, but at the same time it restricts very much the sphere for consideration. It is unfortunate, therefore, that the data available are so limited, being mostly confined to the Peninsula of India. There is one station at Leh in Little Thibet, 11,500 feet high. Four stations from 6000 to 7000 feet high are found on the outer flanks of the Southern Himalayas. With the exception of the three Burmese stations, and two ocean observatories in the Andamans and Nicobars, the remainder are in Ceylon and India. It is claimed that India stands pre-eminent as a field for Meteorological studies as it is isolated by the gigantic mountain ranges to the north, and bathed on two sides by an ocean stretching without a break to the Antarctic lands; and is thus uncomplicated by influences of unknown origin, and uncertain magnitude. If this condition of complete isolation were to be held as literally fulfilled, no help whatever could be rendered by results arrived at from Indian data to the study of the meteorological relations of the countries to the east of the Bay of Bengal; nor would they help much in discussing the general monsoon system circulating round the plateau, as they would neither affect nor be affected, by it. It is, however, probably intended to mean that considered with reference to the varied character and completeness of the phenomena presented, and brought within the field of observation, the Peninsula may be studied independently of its surroundings, and of the widely differing circumstances in which the neighbouring regions are placed. In the Report for 1875 this view is in great measure carried out, and there is little reference to the countries east of the Bay. In that for 1876, this region is brought into more consideration; but not sufficiently to enable any practical conclusions of value on questions as to flood or drought on the Irrawaddy to be drawn. The subject is broached with interest; and there is a great advance on the previous years notice, in a distinct acknowledgment that the south-east quadrant of the monsoon region, or at least that part of it comprised within the Irrawaddy basin lies within the same cycle of influence as the countries west of the Bay. This south-east quadrant can only enter the system as a whole, as it is a compact Peninsula of much the same size and situation as that of Hindostan, and possesses a meteorological system of its own, working on its peculiar lines in detail, but interdependent generally with that of India and the rest of the monsoon region. And it will probably be found that the north-east and north-west quadrants of that region must enter as factors in the study of the general laws of each of the parts. It is likely that a long time will elapse before it will be possible to obtain such excellent observations from the regions as are now furnished in India. It is, therefore, worth-while considering whether the rougher and more general records such as river fluctuations supply might

not be advantageously extended; whether, for instance, exchanges could not be made with the Siamese authorities at Bankok for the river there; with the French at Saigong for the Mekhong; with the English Consular authorities in China for records of the oscillation of the Yangtse-kaing at Ichang, the new, treaty port high up its course; and at other places lower down. Possibly, too, some of the members of that service interested in the subject might be willing to obtain any available data concerning the Hoang Ho; while it is quite possible that systematic notes may be contributed by some of the French Missionaries now resident in Thibet on the head waters of these rivers. Letters from one or more of these constantly come to their brethren here in Burma with valuable remarks and suggestions; and if a spirit of enquiry were roused there is no doubt they would prove worthy successors of the great Jesuit geographers in another branch of science.

On the method in which such record might be made.

21. Before such an interest can be roused as would lead to the ready co-operation of these widely different agencies, it will be necessary not only to make it evident that the object of common research pursued is one of the highest practical interest to all alike—the improvement of the means of studying the phenomena of flood or drought which recur on this wide field of enquiry, evidently subject to unknown though identical causes—but that the duty of securing that improvement is so far recognized that all within reasonable limits that it is possible to do to that end has been put in hard in the range of influence of the Government of India. It is remarkable that not only the most important factors of the outer zone are within that influence—the whole of the southwest quadrant, and part of the southeast, and the great Ocean intervening between these and the equator—but the key of the whole, the great plateau itself can be made to yield indications of its action by the great rivers issuing from it and entering British territory. There can be no doubt that the Salween is the river that comes from the Great Lake Region of Northern Thibet. Whether the Sanpo issues by the Irrawaddy or the Bramaputra may yet be undetermined; but it is certainly by one or the other, and the records of these rivers oscillations would probably in a short time solve the question of themselves. It is certain that between these rivers named much information could be obtained as to the hygrometrical conditions of the interior of the plateau; and that, possibly, in some detail. The northern affluents of the Bramaputra, those of the Ganges, and the Indus with the Punjab rivers flowing into it, would by their separate records show every varying phase of each seasons progress in the most important time for the greater agricultural operations, the summer monsoon. These records are in many cases taken, and the portions made public are of high interest and value, but from the limited extent available and their want of uniformity cannot be useful generally for comparison. The cost of carrying out a uniform system of observation and record for all these rivers would be very slight. Each river basin with all its tributaries could be shown in a single diagram sheet for each year. The rain fall records and perhaps others might be added. Published in the Roorkee Papers they would add to the value of these; and probably pay their own cost. If found desirable the system could be extended to the whole of the river basins of India.

On the co-relation of the phenomena over the whole monsoon region.

22. Complete records of this kind for the last few years might have thrown much light upon the connection or co-existence known to persist between peculiar phases of flood and drought in India, Further India and China. The famine of the first named region, that is, of the south western quadrant of the changing monsoon zone, have been acccompanied by similar famines in Northern Cochin, in Northern China, and in Manchooria, the opposite quadrant. There has also been a singular correspondence between the alternations of flood and drought of India and the eastern peninsula of which Burma forms a part

and which, for simplicity, may be here called the Burmese peninsula, the south eastern quadrant. In the last two years, 1877 and 1878, this has been shown most markedly. The early rains of April and May were unusually noticeable in Northern India in the former year. In Burma there was a total absence of the customary showers of those months; and there was a peculiar condition of intense heat and oppressiveness as the atmosphere accompanied by a prevalence of illness and mortality. In June the summer monsoon set in here with force; and in July and August it attained intense violence both over the Bay of Bengal and over the Burman peninsula to its eastern limits. The Irrawaddy and the more eastern rivers rose to the highest floods ever known. During the same period the early rains of Northern and Western India had disappeared; the customary mid-monsoon supply failed; and the evils of drought and famine were intensified even beyond preceeding years. The same set of phenomena appear to have occurred in Northern China, where the famine reached a climax of horror. It seemed as if the whole monsoon flow had moved towards South Eastern Asia from India and from North China. In the present year (1878) similiar co-relations of events, but with opposite tendencies have occurred. Abundant rainfall in Western India, bringing floods to the Indus basin, to the north-west, and to Bombay with considerable local damages. Abundant rain is also reported from Northern China; and all danger from famine and drought has been removed for the first time for several years. But Burma has this year barely escaped a famine. The condition of the more eastern countries is not known. The floods of Western India were simultaneous with drought in Burma such as has been before unheard of. The planting of rice, which generally takes place in June or July, was deferred through June and through July, and could only commence late in August. At the best it has only been partially carried out in the delta; while large tracts to the north of it are yet unplanted. Fortunately the rainfall of the delta is so abundant usually, that a half supply suffices to ensure a crop, though from the lateness of the planting this must be be less prolific than ordinarily. Since August the rainfall has been heavy; and a high flood rise took place in the Irrawaddy in October to an extent quite unprecedented. It is an immediate inference from the alternation of the foregoing phenomena that some common cause must have been in operation to produce them.

23. Does the monsoon centre on the plateau move more or less north, more or less east or west under changed solar or other influences? Is there only one mid-monsoon centre for the whole region from Russian Asia to Ceylon, from China to Turkestan? Was a determination of this centre, from June to August 1877, towards the south east the cause of the deflection of the whole monsoon flow from the west and north towards that part of Asia? And has an opposite tendency towards the north west during the same quarter of the present year carried with it the altered condition of drought to Burma, of flood and abundance to China and India? These are questions, to answer which one would require to be in possession of the whole of the facts, as well as of a well grounded and workable theory of the monsoon. Possibly with these, and even with complete meteorological and hydrometrical observations for the entire monsoon region, it might be difficult to ascertain the whole of the varying conditions, and assign the causes of the monsoon changes which have such important results to the most populous quarter of the globe. But, on regarding the present rapid progress of meteorological science, and the great advances made in the recognition of the intimate connection of apparently widely diverse atmospheric phenomena, with the successful attempts at explanation and prediction of events, it is not unreasonable to hope that such careful studies as the information asked to be recorded would bring with it will result in a considerable insight into questions as to flood and drought both in Burma, and in all the countries allied in their dependence on the summer monsoon.

The great permanent centre of the monsoon action is on the Plateau.

24. It is even now possible to form a distinct conception of the *modus operandi* of the monsoon; which, though it must for the present admit conjectural elements, is on the whole based on well ascertained facts, and which can adequately explain those facts. The views of Dove that the monsoon is a true and typical trade wind, and those of Mühry that the monsoon has nothing to do with the trade winds, may be in some measure reconciled by a suggestion of Woajeikof. He shows that if the whole surface of our globe were land the heat focus and ascension or indraught region due to the sun's heat would have a wider course than it can have over the ocean. The heating effect is much more rapid on land than at sea. The consequent circulation of cold air below and warm air above would reach from the outer tropic to the further polar zone on each hemisphere alternately. The Asian summer monsoon is a compromise between this state of matters, and that which would result on a globe wholly covered with water. But there is an important difference. In either of the above cases the indraught centre or girdle would never exceed the position of the sun's zenith. It could not go much beyond the 23° latitude. Under present circumstances the indraught centre of the Asian summer monsoon travels far north of this degree, how far is at present unknown. How does this arise? A careful recapitulation of known facts will probably furnish an answer.

An explanation of the monsoon action is possible.

25. The meteorological reports for India show the progress of the monsoon throughout the year within the limits of the field of observation. The plates show the outlines of the peninsula to the south of the Himalayas, and include the coast of Burma. The Isobars, the Isotherms, the wind directions, and the centres of indraught or low barometric pressure are shown for each month. These last do not always coincide with the hottest part of the surface; and the winds are sometimes cyclonic about them, sometimes radial. In January 1875 the low barometric region is in the ocean to the south of Ceylon; with the isobar 29·9 to the north of it. Several places are marked for high barometric pressure on the land, the Western Ghauts, and the countries round the circular front of the plateau, where it records 30.05. In February of the same year one low pressure region has ascended on the land to the latitudes 18° and 20° where it coincides with the maximum Isotherm; while another is apparently trending towards the Burmese side of the Bay. Nothing is seen of this last in March and April. The former has advanced in a north-easterly direction towards the centre of the front of the plateau, towards which the prevalent winds blow from the south and south-west. In May and the next three months this indraught centre has disappeared, probably having mounted the plateau and joined that of the whole monsoon action. The winds still blow from the Bay direct to the front of the plateau; but on reaching this, one branch of the surface wind is diverted toward the north-east of the field where a new low pressure centre has made its appearance. There is nothing to show that this is an absolute low pressure; that is, that there is not still a lower beyond it to the north, outside the range of the observations. It is in the extreme corner of the field in May, June, and July. Probably the true centre will be found on or beyond the Hindoo Kush mountain. In August it descends a little towards the S. E. and is found in latitude 30° longtitude 73° E. Over the peninsula generally, with the exception of the surface current round the front of the Himalayas the direction of the wind is W. S. W. and S. and is such as to lead eventually to the top of the plateau, probably in a current overlying that last described. In September the N. W. low pressure centre has retreated to the S. W. and is found in longitude 70° latitude 29° on its way to the Arabian Gulf. The other centre is on its way back from the plateau, and is found somewhat S. W. of its position in March. In the succeeding months it has retreated from the land to the ocean. The wind directions of the four months are generally the reverse of the preceding four.

The minor monsoon centres travel from the plateau to the ocean through the Indian and Burmese Peninsulas.

The year 1875

The year 1876.

26. For the year 1876 there is a general correspondence of the indications with those of the previous year. The low pressure centre advances from the ocean through Ceylon, and on a curved line trending easterly, through Central India, and to the Assam front of the plateau. It is shown in April in a more northerly position than at the same time of the previous year. The north-west centre has not appeared on the land in April. But the new stations in Burma permit the presence of a separate low pressure indraught centre to be shown on its way to the farther Indian Peninsula. It is shown near Rangoon in March and April. It disappears entirely for the rest of the year. An extension of the observations would probably reveal it taking a position much more inland as the hot weather progressed, and advancing in a radial line to the plateau to join there the great common focus of the permanent monsoon. A corresponding locus of heat and indraught appears to be known in south-west China in the months preceding and following the mid-monsoon. The four last months of 1876 correspond sufficiently with those of 1875 to call for no remarks.

Opposing surface and upper currents in the early monsoon.

27. The diversion of the S. W. winds of the monsoon from the Bay of Bengal into S. E. winds over the the whole of the upper ranges and Indus valleys is the most remarkable feature of the monsoon. These S. E. winds are met by S. W. winds from the Arabian Gulf and local storms and cyclones result. It is doubtful whether the deflected winds are of the full depth of the monsoon current, or are only its lower layer. It is probably the latter. Cases have occurred where phenomena such as heavy falls of rain could only be explained by an upper current from the S. W. direction bringing the humidity. In Assam in 1874, the heaviest rainfall of the whole year, which usually occurs in July, took place in May. (1). Northerly winds prevailed during that month in Assam, easterly ones in Chittagong to the south of it, and south westerly ones in Bengal and Aracan. Mr. Wilson in his Meteorological Report for Bengal in that year says:—"The excessive rainfall in Assam and the adjacent hills in May was one of the most remarkable characteristics of the year. It is clear that the enormous quantity of vapour which was precipitated over these regions must have arrived in some way from the Bay of Bengal. But that it was not carried there by the surface winds will appear from the following statistics" After giving these details showing that the winds were mostly south westerly he says:—"The inference then is that from the heated plains of Northern India in the hot weather months there must be an upper westerly current towards the cooler regions of Assam, above the southerly winds of the delta." This carries the vapour from the Bay above the surface current, which cools the air and precipitates the moisture. Only in this way can the distribution of the great quantity of vapour raised be accounted for.

There is a permanent monsoon, distinct from the trade winds, which centres in the plateau.

28. The researches of Dr. Hooker (2) proved the presistence of southerly day winds in the valleys and on the passes leading to the Thibet plateau even in the depth of winter. At night he found cold north winds. The sun was very hot, and warmed the granite rocks so that they kept their heat during the night. He found the heat was felt less when the wind was blowing. General Strachey (3) observed that the day winds in the more westerly parts of the Himalayas and Thibet commenced from the S. E. about 9 a.m., gradually shifting round with the sun to the S. W. and ending in that quarter about 9 p.m. The night winds blow with great violence at the debouchures of the principal streams into the lower plains, but diminish in force as the mountains are ascended. At great elevations and in the plains of Thibet the nights are almost always

(1.) Meteorological Report for 1874, for Bengal, Mr. Wilson.
(2.) Hooker, Dr. J. H., Himalayan Journals, 1855, page 209 etc.
(3.) Strachey, General Sir R. The Physical Geography of Kumaon and Gahrwal 1851.

always perfectly calm. The day winds on the other hand are here perfectly terrific. The continuance of this manifestation of the sun's energy through the winter when the action is weakest proves the plateau to possess a system of circulation of its own entirely independent and distinct from the general circulation of the trade wind. It has already been noticed that its elevated mountains separate the air circulation of the countries to the south from that of those to the north in the lower half of the atmosphere. It cuts off all continuance of polar and anti-polar winds from the trades in this part. The winter monsoon in India is a true trade wind; that of the plateau at the same period an independent monsoon wind.

The indraught centre of the monsoon never leaves the plateau.

29. That the indraught centre of the plateau never leaves it with the passage of the sun towards the south is established by the foregoing and other observers mentioned by Mr. Blanford, as well as by his own observations. The separate trade wind centres appear to break off from it and pursue their own course southward. The position of the indraught region left behind is somewhat conjectural. It probably extends over the Southern and the Central Himalayas with the intervening high plains; and may reach to the summits of the northern Himalayas, even in the depth of winter. The nearest point of this permanent winter centre to the sun's zenith in midwinter is distant over 50 degrees of latitude. As the sun moves northward the more northerly plains of the plateau and the mountains must share in the increased heat. In midsummer the most distant part of the plateau is not over 15 degrees away from the zenith. The heat energy communicated by the sun to the northern boundary chain, the Kuen Lun, at this time, must far exceed that which makes the southern mountains a permanent indraught centre in winter. If the whole globe were covered with land, the plateau remaining as conspicuous as at present, the heat of the southern part of the plateau would continue to increase with the sun's progress northward, and its indraught and ascensional air current would dominate that of the neighbouring regions. The cooling effect of the vapour brought from the southern oceans in the present arrangement changes this, and establishes a different régime.

It travels from the south of the plateau in winter, to the north in summer, and vice versa.

30. The most intense heating of the southern bounds of the plateau must take place in the hot months of April and May, when the heat centres from the plains approach and coalesce with that of the summit. At this time the S. W. winds are established at sea and near the sea coasts, and in front of the plateau. In parts of the interior country other winds blow. But the upper current from the S. W. continues to reach the plateau. It is probable that a junction is effected at this time between this current, and the moisture bearing winds from the sea. Huc mentions that he was detained for several days, at Ghiamda, to the east of Lassa, in April, owing to a downpour of torrential rain. Nain Sing states that near Lassa the rain commences in April and May. General Strachey reports that in the western Himalayas and plains of Thibet the rains commence somewhat earlier than in the plains below. As air ascends it expands and cools. Its power of retaining moisture lessens; and its relative humidity becomes greater. Finally rain falls and cools the heated earth. Also the moisture laden air intercepts a much larger quantity of heat from the sun than clear dry air. The very intensity of the heat of the southern border of the plateau thus brings about a cooling of the outer margin of the focus; and the regions to the north being relatively hotter, the indraught centre advances northwards. But the heat focus itself extends in area and acquires immensely increased elevating energy with the air. The indraught of this increases at the same time that its own vapour tension increases, and as the evaporation of water over the ocean attains a maximum. The cooling of the southern margin of the indraught centre must therefore progress with the elevation of the moisture and the precipitation of the rain, and the region of air ascension must advance northward until the height of the midsummer monsoon.

31. The position and form of this centre of action must for the present remain conjectural; but can approximately be determined. The vapour bearing winds pass over the valley of Great Thibet; they cover the northern Himalayas with snow and precipitate rain on their northern flanks, but with diminished force. The plains of the Lake Region are covered with grass, sure proof of some modicum of moisture remaining to the air. The Lakes themselves are often without drainage exits. They receive on the whole a small supply of rainfall. It is shown by Dr. Mühry that all surface winds are aspiration winds; that is, are drawn from in front, not pushed forwards. The source of their action, therefore, always lies in front of them. The moisture could only be brought to the northern Himalayas and Lake Region from the south. The heat and indraught centre must thus lie to the north of this region. The Kuenlun mountains are almost unknown; but from the diminishing rate of the humidity and fertility as the winds progress northwards it is probable they arrive at this chain totally denuded of vapour; and that the chain is itself barren. The great desert crossed by Huc, and which deterred Prejevalsky, is a sample of this region. It is eminently calculated to become a heat focus. As it and the mountain chain cannot be subjected to the before described cooling process, no reason exists for the further advance of the heat centre. It is probable, however, that while the position of maximum heat remains on the top of the plateau, the desert of Gobi is included in the area of indraught. In this case the indraught centre—the *Auflöckerings Gebeite*—will have assumed at midsummer the form of an elongated oval whose principal axis lies on the Kuenlun range, and whose dimensions are unknown, and probably variable.

Form and position of the midsummer monsoon centre.

32. From the whole of the observations and records available it appears probable that a double cyclonic circulation takes place about this indraught area. Starting from the central front of the plateau in the Bay of Bengal one set of winds blow from S. E. towards N. W. passing through the north-west of India, the Punjab, Afghanistan, Turkestan, and round to the north of Gobi. This is continually reinforced with vapour from the Arabian Gulf; and radial winds leave it for the central zone. On the other side S. W. winds cross Burma, and circulate through further India, veering round in China towards the north and north-east till they reach Mongolia and Tartary. They also are strengthened by continual inflows from the China seas, and from the Pacific Ocean; and radial winds from them sweep across the river basins of the interior. The barometric pressures, the prevalent wind directions, the rainfall records and hydrometric notes of travellers sustain this view, which is capable of explaining much that without it seems anomalous. The theory connecting diminished solar energy with minimum sunspot manifestations and lessened rainfall in certain localities with both, might explain some flood and drought variations in the monsoon region. With a smaller supply of heat the indraught centre would not advance so far to the north. The winds over the Bay of Bengal would obtain a lessenned supply of moisture through evaporation. Then lowered vapour tension would induce a more ready precipitation over the Bay itself and over the lands immediately neighbouring. The radial components of the winds would carry the moisture more to the south-east quadrant than usual, as the centre of indraught lies more southerly. The cyclonic components of the wind would predominate over the radial in moving through India and through China; and deprived of their full supply of vapour, would have their vapour tension increased over the heated lands of the south-western and north-eastern quadrants. The reinforcements of vapour from the Arabian Gulf on the one side, and from the Pacific on the other would be absorbed and carried to the north-west quadrant, bringing abundant rain. The south-west and north-east quadrants would thus suffer from drought, while the others enjoyed abundant rain, or were subjected to floods. The distribution of rainfall for the year 1876 corresponds with this conjectural case. The Peninsula of India and northern China generally suffered from draught. Towards the extreme north-west of India, and

Motion of the winds about that centre.

CHINESE EMPIRE
TIBET
PUNJAB
Multan
Lahor
Delhi
Agra
RAJPUTANA
LESS THAN 10 INCHES
10 INCHES
20 INCHES
30 INCHES
40 INCHES
50 INCHES
NEPAL
OUDH
Lucknow
Allahabad
CENTRAL INDIA
LOWER PROVINCES
CENTRAL PROVINCES
Nagpur
BERAR
BOMBAY
HAIDARABAD
Hairabad
MYSORE
MADRAS
LESS THAN 50 IN.
50 IN.
60 IN.
40 IN.
ABOVE 100 INCHES
100 INCHES
90 IN.
80 IN.
70 IN.
LASA
BHUTAN
BURMA
Mandalay
Bamo
Kiang Hung
Salween R.
RANGOON
SIAM
BANKOK
HYETOGRAPHICAL MAP
of
INDIA
D

over south-eastern Asia the rainfall was more abundant than usual.

Principal meteorological facts regarding the Irrawaddy Valley.

33. Leaving the field of conjecture, the known facts affecting the meteorology of the Irrawaddy valley, including with this that of the Sanpo, can now be briefly enumerated. The average annual rainfall for Northern India was shewn in a map by Mr. Blanford attached to his wind of Northern India in 1873. Other maps with more extended data are given, with the Progress Reports for India for 1871-72, and 1872-73. That for the latter year is copied roughly, and is now given. It presents at once the most striking features of the rain distribution, and is invaluable in its suggestiveness. No attempt has been made to alter or extend the lines of average rainfall; except a portion of the Irrawaddy valley near Pagan which has been colored as under 10 inches. The fact that this is so appears to be widely known, as Czerny shews it in the same way in his map of the winds (1). The zone of rainfall between 50 and 100 inches in the Irrawaddi valley is probably too far inland; but in other respects the map may be taken as accurate. No attempt is made to show the rainfall of the southern Himalayan slopes above 7,000 feet in height, nor the region beyond to the north. A belt of rainfall of over 100 inches yearly is found on the west coast of India, and a corresponding one throughout the length of the coats of Burma from 10° to 23° N. latitude; and the belt broadens till it reaches the spurs of the Khasi hills south of Assam, where the greatest rainfall recorded, that of Cherrapoonjee, some 600 inches yearly, is found. The belt curves round to the west and north of these hills and is lost against the Himalayas. Within this zone almost every degree of rainfall up to 600 inches is found. Probably some of the western spurs and valleys of the Aracan range nearly reach this rainfall. The stations on the sea coast below, Sandoway, Kyouk Phyoo, and Akyab, average from 200 to 300 inches. The Assam valley lying to the north of, and behind the Khasi hills, is shown with a minimum rainfall of 70 inches. By far the greater part receives above 80 and 90 inches. The record is not shewn to the extreme north east of the valley. As the Khasi hills average from 5,000 to 7,000 feet high and the mid-monsoon current is there of a much greater, though unknown, depth, they can cut off only a comparitively small portion of the vapour from the monsoon flow. It is true the vapour tension of the air is higher, and the density of the vapour contained in it greater in the lower strata than in the upper ones; but there is no reason to suppose that in the midsummer monsoon, when the evaporation over the sea is most active and the indrought towards the plateau most intense and strongest, the first mile of air from the surface towards the north of the Bay contains the larger portion of the moisture conveyed from the sea and distributed over the land. The falls of 90, 80 and 70 inches of rain on the lower plains of Assam behind the Khasi hills prove that the air in the most disadvantageous circumstances possible can part with what in any other country would be a heavy supply of rain. The tendency of the whole current after striking on the hills must be to rise and proceed to the Himalayan front. It again strikes against these; and as, in obedience to the indraught to the top, it rises and cools, its vapour tension lessens, and its ascent must be marked by a succession of heavy rainfalls. The Bramaputra watershed is probably the one that has the greatest comparative rainfall in the world. Its numerous large tributaries and its own gigantic size are proportioned to this supply. Great as they undoubtedly are no far distant source of supply is needed to account for the immense discharge of water to the sea by its channels.

Map of Indian rainfall.

The rainfall on the Sanpo valley.

34. There is no clue to the quantity of vapour that reaches the interior of the plateau, and is deposited there as rain, except such as the statements of Bogle, Manning, Huc and Nain Singh furnish. These are not sufficient to define accurately either the commencement and end of the rain-

(1) Czerny Dr. Die Wirkeurngen der Winde &c., 1876.

fall, its average amount or period of greatest intensity. We know that it commences somewhat earlier than in the plain of India; that the Sanpo has acquired large dimensions to the south and east of Lassa, where it flows over a wide sandy bed; and that its probable maximum discharge in the height of the rains is not less than three quarters of a million cubic feet per second, from an area of under 150,000 square miles. The *thalweg* of the river lies in a deep trough from 10,000 to 15,000 feet lower than the mountain ridges to the north and the south of it; and about the same above the sea. Its great depth shelters it from the ruder storms; and the greater rainfall must be on the higher slopes of the northern mountain. The great length of the valley, nearly 1,000 miles, and its comparative narrowness, never over 150 miles; with its position stretching from west to east right across the path of the mid-monsoon on its way northward favors its receiving a large supply of rain. The melting of the snows must furnish a relatively small discharge to the river. To the south of the Himalayas, General Strachey estimates the height of perpetual snow to be 15,500 feet; to the north from 19,000 to 20,000 feet. Dr. Hooker gives the corresponding figures at 14,000, and 18,500; the brothers Schlagentweit at 16,000 and 17,000 feet respectively. The differences are probably accounted for by the difference of the places observed; but it is evident that the quantity of snows lying within the limits of the valley of the Sanpo must be comparatively small. In the beginning of the monsoon, and particularly in the hot months of April and May, it may nevertheless yield a not unimportant contribution to the whole discharge, and cause small rises in the channel; but even then these are supplemented by heavy downpours such as that experienced by Huc in April at Ghiamdo.

The snow line on the Himalayas.

35. Ghiamdo lies in a small valley towards the extreme east of the Sanpo valley; and is drained by a river flowing into this. Huc's account of this torrential rainfall in April singularly corresponds with Dr. Griffith's account of a rapid rise of flood in the Irrawaddy at and above the mouth of the Mogoung river in the same month; but nine years earlier. He and Dr. Bayfield had descended the Mogoung river which they found low, with a slight stream almost to its mouth. On entering the Irrawaddy, however, they found an immense flood passing down it from the north. It was then April 23rd 1837. The river rose enormously during a halt at Tshenbo. In one part of the Tshenbo defile the rise was ten feet in one night. Dr. Bayfield estimated the velocity of the current in the defile to be from 12 to 15 miles an hour. The body of water passing down in this sudden flood must have been enormous. The flood was falling again when they arrived at Bhamo on the 27th April. Such a flood as this could hardly come from the Burmese tributaries of the Irrawaddy. The region about Mogoung appears to have had no unusual rainfall at that time; nor does either Griffith or Bayfield note any such state of the atmosphere in their neighbourhood as must inevitably have accompanied a downpour of such an extent within a range of 150 miles. The flood could only have come from Thibet. It was of too sudden a nature to be due wholly to the melting of the snows. Its violent rise and fall prove it could not have been from the remoter part of the Sanpo valley. It in all probability came from the Kenpou or Tchi-tihom-tou minor valleys to the immediate north of Burma. The necessity of allotting a much larger drainage area to the Irrawaddy beyond this part than has of late years been ascribed to it has already been treated at length: and the grounds given for connecting it with Sanpo. No other course is open, if the whole of the accounts of the Upper Irrawaddy yet received are not to be rejected. It has been shown that its channel at the mouth of the Mogoung river is somewhat larger in capacity than that of the Sanpo in highest floods. The Sanpo where last known is at an elevation of some 10,000 feet above the sea. It is reported to have enormous cataracts in the unknown region between this and the plains. Neither the Niagara nor the Zambesi discharges such a mass of water, nor can

The floods in the Irrawaddy coming from Thibet.

have such enormous falls as this mysterious river overcomes. However much of its total fall is passed in precipitous cataracts the remaining portion of its bed must have an exceedingly steep declivity. Wherever it issues into the plains it must do so in a restricted channel, and with a velocity unknown to all other rivers. The 750,000 cubic feet per second of its high rises in the valley above may be somewhat moderated to a more prolonged flow at a smaller rate; but both in volume and velocity it must be discriminated beyond possibility of doubt from other streams by the characteristics due to its mass and its fall from the high level to the lower. It is proved by Strettell's description of the lowest dry weather discharge at the highest point of the Irrawaddy known, that this issues with extreme violence from the hills. The flood discharge will exaggerate this violence to the utmost limits. Griffith's and Bayfield's description but confirms what might have been anticipated from a flood rushing with great acquired velocity from the higher mountains. Such quiet fordable mountain streams of low elevation as Wilcox saw could never accumulate a flood of this kind near the Mogoung river; and it must be looked upon as absolutely certain that the principal source of the Irrawaddy floods even in the delta lies in far distant regions, much beyond the limits of the Burman valley.

The Irrawaddy valley where visited by Wilcox. Its rainfall.

36. The indications available regarding the Irrawaddy valley from latitude 28° to latitude 24° are few. The highest part visited is that reached by Wilcox and Burlton in latitude 27½° in May 1826. The bed of the minor valley from which they returned was at an elevation of 1,855 feet above the sea. The boundary ridge between it and Assam was about 8,000 feet; and they crossed a snow covered mountain nearly 13,000 feet high. The rains had set in. They were harassing to the travellers without being of extreme violence or very continuous. The streams were in flood. The nights were cool; the thermometer at sunrise was from 72° to 78° in the shade; and at the hottest time from 84° to 94°. They returned to Assam in June without having seen the principal channel of the Irrawaddy.

The two northern branches of the Irrawaddy and the northern tributaries.

37. This main channel is formed in latitude 26° by the junction of two large branches, that from the east, though called Myitgney, or little river, being the larger. The courses of both of these beyond latitude 26° are unknown. They have only been seen in extreme low water by Mr. Strettell in February 1874. From the junction to about latitude 25½ the river is a succession of rock-bound gorges, with the stream rushing with a loud roar and great violence over white granite boulders even in lowest water. The mountains close in on either side. No cultivation is to be seen. In one place the gorge narrows down to about 150 yards in width. The banks show signs of being flooded in the rains. The channel becomes more open from there to the Tshenbo defile. It receives the Namtha-bet and Nam-ma-be streams on the left, and the Mogong river on the right. None of these tributaries is large. They average from 100 to 150 yards in the plain land; and are navigable for some distance in the rains. Hannay noticed that the banks of the Irrawaddy in this part bore marks of flood over them in the rains. The whole flat country appears thus to be liable to submersion. The Taping river enters on the left bank on about latitude 24½°; the Shueylee near latitude 24°. No other streams of magnitude enter till to the south of Mandalay.

Notes of the expedition to Yunan on the Taping valley and on the Irrawaddy in 1868.

38. The difficulties of navigation and those arising from the anarchical state of the country have prevented Europeans observing and recording the progress of the summer monsoon in the Irrawaddy valley to the north of Bhamo. The valley of the Taping to the north-east of Bhamo is the only one where such an opportunity has been presented. The expedition to Yunan in 1868, under Col Sladen, left Bhamo early in the year. It stayed in the Kachyen

hills 20 miles from Bhamo, elevation 2,700 feet, from the middle of March to the 11th of May; when it left for Momein, which the party reached on 26th May. This place is a fortified city at 5,800 feet elevation, at that time in possession of the Panthay rebels. The party remained there till 13th July; returning slowly by Muangla and Sanda in the Sanda valley of the Taping, and by Hotha in a small lateral valley to the south. They reached Bhamo on 5th September, leaving this for Mandalay by boat on the 13th. The writer was in Prome till June, and passed up the river by boat to Bhamo, and up the Taping to its exit from the hills; meeting the main party at Muangla on 15th July. The monsoon was thus noted in two aspects in the early part of it; on the Upper Taping; and on the main channel of the Irrawaddy. Reports were published separately by all the members of the expedition, Col. Sladen, Dr. Anderson the naturalist, Captain Bowers, R.N.R., and the writer. That of Dr. Anderson is most convenient and useful for reference with regard to the meteorology observed on the journey, an abstract of which is appended. Regular observations were taken by him, as far as possible, under very difficult conditions. Wind observations were kept regularly at 7 A.M., at 4 P.M. and at 9 P.M., on both the upper current and the lower, where the cloud movements permitted this. Hygrometric and barometric observations were also taken, till the instruments were stolen. The observations are particularly valuable as the year 1868 was one of very high flood throughout the course of the Irrawaddy in Burma.

The rainfall in the Taping valley in 1868.

39. In March and April northerly and easterly breezes came at night, while S. W. ones prevailed in the day time. In May, the surface winds were northerly at night; while the upper flow at the same time, and during the day both upper and lower, came from the S. W. From June to September almost all the winds were from the S. W. Only a slight shower or two is noticed till 11th April, when a storm came with thunder and hail. It rained at intervals day and night, with thunder and lightning till the 18th; a lull with one storm on the 23rd April then occurred till 1st June. It then rained almost every day and night through the month. In the early part of July occasional showers fell; but the weather was more broken. On the Irrawaddy an early unusual rise with a rapid after fall occurred in May at Thayetmyo and Prome. It was a small flood wave passing down the river from the higher parts of the basin. The latter part of May and the first half of June was marked by a very low stage of the river, as far north as Mandalay. The river rose rapidly above Mandalay after the middle of June, and was in full flood towards the end of it at Bhamo. Its surface was within 3 or 4 feet of the highest flood marks, covering the lower banks so that the boats were able to pass through paths cut in the forests. The highest rise was on the 25th, when it commenced to fall. In the first half of July it rained generally morning and evening near Bhamo, and in the Kachyen hills. The mid-day was often fine. At times the air seemed saturated with vapour, wetting every thing, though no rain fell. Then a smart heavy shower would clear the air, and opening up the view show waterfalls breaking over the rocks, every rivulet increasing in size to a rushing stream; the streams becoming torrents; and the Taping foaming yellow with silt, and scattering spray high in the air as it dashed against the rocks and boulders in its course through the gorges. It falls here 2,000 feet in 15 to 20 miles. The plains below were flooded. There the stream was comparatively mild, not over 10 or 12 feet deep, and 400 to 600 feet broad. In the latter half of July it rained heavily on several nights, and in the mornings, with occasional breaks of fine weather in the day; the last week improving. But on the 31st July and the 1st August the valley was visited by a tremendous deluge of rain. On the morning of the 2nd it was noticed that the sides of the mountains which rise to the north and to the south of the valley to 2,000 and 3,000 feet above it were heavily scored with enormous landslips. Every rivulet and stream issuing from the hills

The flood rise in the Irrawaddy 1868.

Destructive effects of heavy rainfall in the valley of the Taping.

to the plain part of the valley, which is here 8 to 10 miles broad, had thrown down a large cone of deposits which radiated fan-like over the plain. The main river in the lower part of the valley had inundated its banks some feet deep. News came in that some whole villages had been buried or carried away by the land-slips and several hundred lives lost. On preparing to cross to the Hotha valley, a few days after, it was found that strips of land many miles long and one or two wide had been submerged and covered with a deposit of mud, ruining the rice cultivation. The valley just above the entrance to the gorge through the hills, had served as a reservoir to hold the water. When crossed, the high flood had fallen. Men and ponies were able to swim over. The water spread over from 400 to 600 yards in width; but was in no place above 6 feet deep. The flood and the damage caused by it were entirely unprecedented; and is still associated in the minds of the people with the visit of the party. That numerous lives were lost was verified by the statements at Bhamo that many bodies had floated by there. An exceptional flood of this kind would, if confined to the Taping valley, have no great effect on the Irrawaddy. The discharge would be moderated on its passage down the gorge, and the rush at the bottom would spread it over the already flooded plains to be more gradually drained off by the main river. But if the rain storm passed simultaneously over a large extent of the 30,000 or 40,000 square miles of the upper tributaries and Burmese valley of the Irrawaddy it would account for a very high flood even with the great capacity of the channel at Bhamo. That this storm had no such disastrous effect in the immediately contiguous valley of Hotha to the south was learned eight days afterwards in that valley by the party; and at Bhamo in September there was no news of great storms or damage elsewhere, though all particulars had been received of that near Sanda.

The influence of the people on the hydrological condition of the Taping valley.

40. The devastating results of the rain on the mountain sides in the Sanda valley are in a great measure due to the disforesting of the slopes. Excepting the sacred banyan, and a very few trees carefully preserved from destruction, there is scarcely a forest tree or anything larger than small shrubs visible in the valley. The plain portion of it is densely populated by Shans and Chinese, living in large organized communities. For their use in building and for firewood almost every thing that can burn or be cut up has been removed; and all such materials are now brought in from great distances by Kachyens on mules. The Kachyens occupy the higher mountain slopes. They are seldom found in the plains. They are divided into numerous families and clans with separate chiefs; rarely combining, and often hostile to each other. They are demon-worshippers. Their houses are usually long thatched sheds with wooden floors raised from the ground. Sometimes these houses are 200 to 300 feet long with several families residing in them. They cultivate the hill sides in terraces, generally near the water-courses, whence they irrigate the small patches. They seem amenable to judicious influence; but their limited appliances permit them to extract only slight results from extended areas; and they press hard on their means of subsistence. A summary settlement of differences by fire and sword serves to regulate their conduct to each other; but from various causes they have of late years been exceedingly aggressive with the Shans and Burmese of the Irrawaddy plains; and they have depopulated immense tracts of country. The Shans show great facility in following the customs of their neighbours. The Chinese Shans, those who reside within the Chinese boundary, have adopted the pigtail, the chopsticks and the dress of the Chinese. They build in the same style, with houses on the ground, neatly separated from each other by yards and walls; and keep to the peculiarities of the Chinese system of Budhistic ceremonial. They are highly organized in states, with hereditary chiefs, who are preserved as a cherished symbolism without possession of much power. Their habits are industrious. The Shans of the Burmese valley have adopted all their modes of life from the Burmese. They live in small wooden houses raised several feet from the ground with thick thatched roofs, and open fronts. These

are ranged side by side on the two sides of long streets, of which their villages are mostly composed. They tatoo their bodies, wear long hair, and in their general practices and religious ceremonies adhere closely to Burmese modes.

The floods from the Upper Tributaries.

41. The Kachyen mountains when removed from these close-lying Shan villages are densely wooded. Chestnut appeared to prevail from two to four thousand feet; but virgin forests clothe the whole hills to 6,000 feet. Rain continued at intervals through August and September; but except on the occasion of the great inundation it never assumed the steady unmitigated downpour such as occurs in Rangoon and near the sea. In the absence of rainguages, and judging from the rainfall experienced in Prome and Henzadah, where it ranges from 50 to 100 inches yearly, it appears probable that in 1868 the rainfall in the neighbourhood and to the north-east of Bhamo was not less than 50, and not over 100 inches. The Taping valley may be taken as representative of all the north eastern tributaries of the Irrawaddy; though probably the Shweylee to the east, being more protected, will have a smaller average fall; and there is every reason to suppose that that of the Mogoung river and the lesser streams to the west must also be smaller. The whole of the area drained by these upper tributaries of the Irrawaddy in Burma has been estimated at about 20,000 square miles. If the main channel of the river were full or nearly filled by a steady discharge from the Thibetan highlands, the contribution from these tributaries under the conditions witnessed in 1868 must inevitably produce an acute state of flood in the river from Bhamo to Mandalay. This part of the channel is for a length of over 150 miles hemmed in and restricted by parallel ranges of hills which leave no room for the flood waters to spread out in the valley. The channel itself is narrow, and confined by rocks through most of its length. No streams or tributaries of any size join it in this length; the largest, the Madra, being quite unimportant. There is thus no room for a flood arriving on an already filled channel to moderate itself before reaching Mandalay; and that this was the case in 1868 was found by the expeditionary party on their return there in September of that year. The whole city had been inundated to a depth of nearly three feet. Grain crops and flourishing fruit gardens had been destroyed, and though from the character of the majority of the houses, wooden structures raised on piles, no damage had resulted to them, an unpleasant deposit of silt was left over the city. The flood itself was deemed there to have been a very extraordinary one.

The flood of 1868 at Mandalay.

The Irrawaddy channel south of Mandalay.

42 Lower down the river the whole way from Mandalay to the delta the flood of 1868 presented the character of being abnormally high. It breached some unfinished embankment works near Henzadah; and as it gave the highest flood rise on record, its limit formed the datum line to which the construction of future works was to be referred. Nearly 300 miles of river channel intervene between Mandalay and the delta, over 170 of which to the north of Magwe are in comparatively open country, with broad plains on each side of the river liable to inundation, while the river itself spreads out in floods to four and six miles wide with various channels and changing islands. This portion receives what has been called, reverting to a former illustration, the drainage of the body of the vase-shaped basin. The remaining length of 130 miles from Magwe southwards to Saiktha receiving the drainage of the neck of the basin is rock-bound by spurs from the Aracan Yoma to the west, and from the Pegu Yoma to the east, the main ridges themselves closing in upon the river. In this part very few islands exist; though great alluvial banks move about from year to year transposed by the floods. It is obvious that the river channel, especially in the broader part, must act as an enormous reservoir to store up the mass of a flood wave coming from the north, if the channel be not already filled; and that the outflow at the delta even in the latter case would be modi-

fied and moderated, unless a continual afflux of water took place from either or both the regions mentioned—the body or the neck of the valley. It is necessary therefore to consider the condition of each of these in their action on the flood discharge.

The arrangement of the upper tributaries.

43. The greater area of the upper tributaries of the Irrawaddy lies to the north-east of the river, the valleys and hills presenting a peculiar conchoidal arrangement, one curving within the other; and the head waters of the lower ones reaching probably to the north-east of the higher inflowing but smaller streams. The whole of these come from the north. The Mogoung drains a comparatively small area to the west of the Irrawaddy, and is made of a T or Y shaped basin, with one branch from the north and one from the south. Outside of this to the west and north of its sources lie the head waters of the principal branch of the Kyendwin, which rises very nearly as far north, in latitude 27°, as the supposed origin of the Irrawaddy. This branch flows nearly due north and south to join the main river in latitude 21° 50′. It receives two tributaries from a Y shaped basin with branches from the north and south, like that of the Mogoung, but larger. The northern one, the Nam-kathey comes from the state of the Munipoor, the other, the Myit tha, is little known, but appears to rise about latitude 21° and flow north to unite with the former and join the Kyendwin in latitude 23°. The Moo river is a very unimportant stream lying between the Kyendwin and the Irrawaddy. The Kyendwin and its system absorbs the major part of the western drainage area of the upper Irrawaddy. The Myitgney resembles the Mogoung basin in shape, with northern and southern tributaries; but is somewhat larger in extent. Both it and the Kyendwin flow into the Irrawaddy within 30 miles from Mandalay, and as they are situated in somewhat similar meteorological conditions, their common action in flood must be important to the Irrawaddy.

The Kyendwin and other lower tributaries.

Physiographical condition of the Irrawaddy basin.

44. These conditions, though probably homogeneous for the Upper Irrawaddy basin as a whole, affecting each part of it simultaneously in the same way, as by increased rainfall towards flood, or by the reverse to draught, are considerably modified in their effects on the floods of the Irrawaddy by the position in which the tributaries enter; by the physical and geological structure of the basins; and by the share of the rainfall which each part receives. Local storms like that which swept over the Sanda Valley in August 1868 cannot affect the entire river basin; but from its compactness, and from the fact that the various minor basins of its tributaries lie side by side across the direction of the monsoon current, they must share in common the effects arising from the characteristics of this. The arrangement and the structure of the boundary mountains are the principal modifying conditions both in distributing the rainfall brought by the monsoon; and in regulating its discharge into the main river channel. Of the two great ranges which, coming from Thibet, separate the Irrawaddy valley from Aracan and the sea on the one side, and from the Salween on the other, the Aracan Yoma is that which contributes most to the first discrimination of the rainfall on the several parts of the valley. The height of the main ridge, which is about 8,000 feet where crossed by Wilcox in latitude 28°, lowers gradually to the south. Where crossed by Griffith and Hannay in latitude 25¾° it was about 4,500 feet high. The Aeng Pass in latitude 20° is 4,664 feet above the sea. Tonghoop Pass (18½° N.) rises between 3,000 and 4,000 feet. The crest of the ridge, and the principal peaks, of course rise considerably above the height of these passes, which are the lowest and most accessible points of the whole range. For the whole length of the main body of the valley north of the British frontier, the mountain averages about one mile in height, and acts as a screen to cut off the most richly laden layers of the vapour bearing winds from the Bay of Bengal.

45. The general direction of the Aracan Yoma is from north to south; though it curves like a bent bow to the west. In geological structure it is closely allied to the southern and western Himalayas. It consists of groups of two eras. According to Mr. W. Theobald, Geologist in Burma, there is an axial nucleous of granitoid rocks of the Triassic period, in which the same fossils are found as in the north-western Himalayas. Outbursts of serpentine occur in this bed; which is most largely devoloped in Upper Burma, though there is an out-crop of it south of the frontier. Over lying the Triassic rock is a series of sandstones and shales of the early Tertiary. The Aracan Yoma is, in all probability, the true continuation of the southern Himalayas. It has been noted that no gold nor any of the nobler metals are found in these ranges. Apparent exceptions occur in the mountains round the Bramaputra, all of the tributaies of which are auriferous. There is no gold found in the Aracan Yoma west of the Kyendwin; but it is curious to note that the whole of the eastern affluents of this river yield gold. The range which separates it from the Irrawaddy breaks off from the main ridge in latitude 27°, and bifurcating in about 23¼ encloses the Moo basin. Platinum and silver are found in this range.

The Aracan Yoma.

46. A similar anomaly as to the presence of these nobler metals is found in the eastern boundary chains. This is undoubtedly a prolongation of the northern Himalayas. In height it appears to correspond closely with the Aracan Yoma. Momein which is not at the summit of the pass on the Bhamo-Yunan Road is 6,000 feet high. The Shan Yoma and plateau is very little known. Dr. Richardson in his journey over it from Moulmein to Ava in 1837 records some heights obtained by boiling water on the more level part of the table land as over 4,000 feet (boiling point 204°). The Nat-tike Pass which he crossed in latitude 21½ is said to be much higher,; but is on a spur and not on the main ridge. The true continuation of this range lies to the east of the Sittang. The Pegu Yoma is connected with this range above the frontier by a spur; but has no affinity with it geologically. The former is auriferus throughout its length. In its higher parts the silver and lead mines are locally famous. The Pegu Yoma on the contrary shows no signs of these metals anywhere. The connection between this range and that of the Shan Yoma seems accidental. It occurs about 20° 25′, the northern end of the range terminating to the south of Ava. Between it and the Shan table land rises the southern branch of the Myitgney. The opposing valley to the south includes the Sittang basin. The average height of the Pegu Yoma is from 2,000 to 3,000 feet, with occasional peaks rising higher. It runs due north and south and terminates at Rangoon. It is wholly of a later period than either of the Aracan Yoma groups; probably middle or later Tertiary.

The Shan Yoma.

The Pegu Yoma.

47. Detailed accounts of the geology of portions of the Irrawaddy valley and boundary mountains are given by various writers (1). It is, however, only in their comparative permeability to water and consequent effect on the floods that they have to be considered here. From this point of view they may be classed in three groups :—1st; The rocks of nearly total impemerability. 2nd; The rocks and strata of more open structures and slight permeability. And 3rd; The strata of increased permeability, and considerable storage capacity for rainfall. The first class are found in the granitoid gness and metamorphric rocks of which the greater part of the eastern mountain ranges of Burma, excepting the Pegu Yoma, are constituted. The

Geological structure of the boundary mountains.

Impermeable rocks.

(1) For the Kyendwin valley : Captain Pemberton : Report on the Eastern Frontier, 1838 : The Kachyen Hills and Taping Valley. Dr. Anderson : Report on the Yuman Mission, 1869 : The Irrawaddy Basin. Dr. Oldham : Report on the Thyetmyo Coal Fields 1855, and Report on the Geological Features of the banks of the Irrawaddy, Yule's Mission to Ava in 1855. The Delta. Reports of W. Theobald Esqr. Geographical Surveyor; and a Paper in Burma Gazetteer, 1879. Major Spearman.

same class of rocks form the principal part of the Upper Aracan Yoma with the secondary ranges lying between the Kyendwin and the Irrawaddy. These rocks are not absolutely impermeable; but the first continuous showers of the monsoon serve to saturate them, when they precipitate at once into the rocky beds of their drainage streams almost the whole rainfall in the mid-monsoon The forests and the agriculture of the Kachyen hills appear to have little effect in modifying this discharge, as the rocks are but slightly clothed in their steeper parts with the soil resulting from weathering and degradation of the rocks. Some influence must nevertheless be ascribed to the forest verdure; but sufficient observations do not exist to enable it to be defined with precision. These rocks are, as a rule, only exposed in the steeper mountain slopes in the northern portion of the Irrawaddy basin.

The slightly-permeable rocks.

48. The second class includes rocks and strata of varying conditions of hardness and permeability ranging from hard and compact sandstones, clay shales, and limestones, through the coal measures, iron bearing strata, and softer sand stones of the later groups of the Aracan Yoma and the whole of the Pegu Yoma. The exposed portions of the mountains and hills of the lower part of the Irrawaddy basin from Mandalay to the sea consist of this class of rock. In some parts of the Aracan Yoma east of Prome and Thyetmyo the higher slopes of the mountains are made up of a hard sandstone almost as impermeable as the granite; and which throws off the rainfall rapidly after the first few showers. But the hills are more gently rounded as a rule and retain more of the softer debris of disintegration, where a closely packed bamboo jungle alternates with forest trees. At the height of the monsoon after a month's continuous rain, when the ground is saturated, it is probable that the whole of some of the heavier showers is thrown immediately into the body of the streams, which come down as torrents to the Irrawaddy, especially in the neck of the basin from Magwe to Saiktha; where no plains or great lengths of channel interpose to receive and moderate the first rush of the floods.

The permeable strata of the Irrawaddy basin.

49. But the greater part of the centre of the Irrawaddy valley, both near the main channel, and in the valleys of its principal tributaries, the Kyendwin, the Myitgney, the Shweylee, and the Taping, is made up of broad plains of alluvial deposit, the washings from the neighbouring mountains for countless years. The character of these varies from the easy permeability of the most recent deposit, the alluvious of the delta, to the softer sandstones and gravel beds distributed through the plains and lower hills of the more northern tracts of the valley. The delta formation, where the richest and most fruitful rice fields are, is in general a loose mixture of clay and sand as loam. Water flows through it readily. The wells in all parts of the delta plains have their water level from 20 to 40 feet below the surface in the dry months of March and April; but they rise even with it in June and July when the ground becomes saturated. The water then lies over the whole country clear and sweet within the raised brims of the rice fields. It is, however, only by its continual replenishment from the heavy constant rain from July to September that the elevation of the water necessary for the maturing of the rice, is kept up. A few days of drought dry up the whole surface; and underground percolation is very rapid. The character of the lower ranges and spurs of hills immediately leaving the river channel from the delta to Mengoon and Magwe is mixed, partaking of both the second and the third degree of permeability. It is limited in extent, and cannot have much effect on the river, as the steeper and higher ground behind on either side predominates, and belongs mostly to the second class. But the broader plains and rolling ground from these towns north to Mandalay including the petroleum beds of Yaynangyoung and the site of the abandoned city of Pagan must be classed with the most permeable strata Horizontal layers of gravel and pebbles lie upon and alternate with beds of sandstone generally soft and porous. Occasionally ferruginous and calcareous

rocks intervene, but not in sufficient quantity to change the character of the country. The region about Pagan is arid and barren. No trees exist, only a few prickly shurbs. Not only does very little rain fall, but the soil is so porous that it could hardly retain it, if it came. The complete preservation of even the oldest monuments from destruction by atmospheric influences proves that this arid state has been permanent for over 1,000 years; as Pagan is supposed to have been the capital of Burma from 800 to 1,280 A. D.

The torrent influents of the Irrawaddy.

50. Through these horizontal permeable beds torrent streams rush from the hills behind. Their rise and fall is sometimes extremely rapid; and in the lower stages of the Irrawaddy, considerable influence is exercised on the river by them. But the velocity acquired by the water in descending the hills is lessened in the more level plains; the streams rise over their banks; the overflow penetrates the open soil and is stored up for evaporation or slow drainage. This appears the most important function of the arid plains. It interposes a vast extent between the gathering grounds of the torrents and their debouches in the river; and gives time to moderate the excessive suddenness of discharge from the impermeable mountains of steep slope before reaching the river. The expeditionary party to Yunan in 1868 had the opportunity of seeing this moderating action of the absorbent plains of the Sanda valley in operation in the tremendous local storm of August already related. And the writer witnessed, and had to traverse the flooded plains between the exit of the Taping from the hills and the main channel of the Irrawaddy on the same journey. The best example of the efficacious action of the plain land due to its permeability and its extent of surface is perhaps found in the Kyendwin valley, where the violent floods which result even from the moderate rainfall on its higher mountains, are changed into a comparatively regular and tranquil discharge into the Irrawaddy

Moderating effects of the plain land.

The Kyendwin and its highly moderated discharge.

51. The principal or eastern branch of the Kyendwin rises to the east of Assam near the 27° N. latitude, and to the west of the Mogoung river It receives several considerable affluents on its way southward; which, according to Captain Pemberton (1), bring down sudden floods of pure and transparent water, remarkable for the small quantity of silt. These streams generally flow with great rapidity, over pebbly beds. In the Kulo part of the valley the excessive rapidity of the river causes the whole of the plain land to become a sheet of water. These inundations extend over the whole of the lower part of the valley, frequently flooding it to a depth of three or four feet; which, however, here fertilizes the ground so that abundant crops of rice are obtained. Parts of the valley are very feverish; but the houses, being of the usual raised Burmese type, are never damaged. From these flooded plains the discharge to the Irrawaddy is even and regular. The great branch from the northwest, the river of Munipoor, presents similar characteristics in its upper parts. The Munipoor valley occupies the head water region of this river. The plain land is at an elevation of about 2,500 feet, the boundary mountains to the west of the Aracan Yoma rising from 5,000 to 8,000 feet above the sea. The higher streams rush clear and free from silt over rebbly beds; but on emerging from the defiles become turbid; and, during severe pains, rise over their banks, converting the whole of the central portions of the valley into a vast swamp. The lower part of this region is permanently a series of lakes and of marshes. One—the Sogta Lake—is of considerable extent. They are a marked feature of the country; and while they furnish grass throughout the dry weather to ponies and cattle, in the rains they regulate and moderate the flood discharges to the Kyendwin and to the Irrawaddy.

(1.) Pemberton Captain. Report on the Eastern Boundary

52. A most important factor, which cannot be too much insisted upon, in moderating the effect of tributary floods on a main channel of a river, is the distance that interposes between the area where the rainfall is received, and the point where the flood rise is considered. This effect would make itself felt in the open channels of rivers and streams independently of the permeability of the strata in the channel; and of the evaporation by the air of a portion of the discharge; though these even in unfavorable circumstances must have some influence. In Belgrand's great work on the Seine (1), he shows the importance of the position and distance of minor tributaries in flood formation on a main river. The discharges of the smaller streams do not fill this channel at the same time, even when the rainfall is simultaneous over the whole reception area. The lower streams have contributed their quota and the channel has disburdened itself in great measure at its lower extremity before the discharges from the upper streams reach that part. This action is fortunately most efficacious when the streams flow from impermeable strata of steep slope; otherwise short and sudden widespread showers would bring continually recurring disaster. It is rarely that a prolonged heavy downpour of rain spreads over a very wide area; and time is thus afforded to distribute and regulate the flow in the principal streams. In the long narrow valleys through which all the larger tributaries of the Irrawaddy flow, receiving continual accessions from the innumerable torrent streams rushing down the steep impermeable mountain slopes, this effect is of the very highest importance in moderating the discharge into the main river channel. The moderating power is roughly proportional to the distance of the centre of area of the reception basin from where the minor river enters the larger. Applying this rule to the principal affluents of the Irrawaddy we find, remembering that the basins of reception of all of these lie behind and within the screen of hills separating them from the Irrawaddy plains, that considerable distances intervene with each. The centre of the reception area of the Shweylee, the largest of the upper Irrawaddy tributaries, is quite 200 miles from the large river. Those of the Taping and of the principal branch of the Mogoung are nearly 100 miles away. The centre of the Kyendwin basin is about 300 miles from the Irrawaddy junction; but that of its Munipoor branch about 250 miles. The basin of the Myitgney is made up of several long and narrow valleys whose reception areas lie at a mean distance of from 100 to 200 miles from where their united discharge enters the Irrawaddy.

The moderating effects of a long channel, and of distance on the flood discharge.

Great distance of reception basin of Irrawaddy Tributaries from river channel.

53. Before proceeding to consider in detail the meteorological conditions connected with the rainfall it is desirable to resume briefly the result already acquired by the analysis to which the data available regarding the river and its basin have been subjected. However vague and imperfect these data may be on matters of great importance, sufficient certitude exists as to the general features of the river and its surroundings to form what may be called a first approximation to a correct knowledge of the process of flood formation in the main channel of the river. In the Burmese valley the limits and principal features of the basin of reception are known with some precision. It stretches from the Thibetan plateau in latitude 28° to the head of the delta in latitude 18°; over about 690 miles. Its extreme width reaches from longitude 93° to longitude 99°, or about 370 miles. Its area is from 125,000 to 130,000 square miles. It is convenient to consider the various parts of this separately, as they affect the floods differently. Thus the northern tributaries, and the whole of the basin draining in the channel to the north of Mandalay, comprising some 30,000 or 40,000 square miles are homogeneous in their action on the floods. The measurements of the river at Mandalay, at Bhamo and at the Mogoung river, above the entrance of the highest of its upper tributaries, and where the Burmese basin

Resumé of data available regarding the Irrawaddy basin.

(1.) Belgrand M. La Seine. Etudes hydrologiques, 1872.

is inadequate to account for the immense volume of water, prove that from 800,000 cubic feet per second in ordinary flood to 1,000,000 cubic feet per second in extreme high flood exists in the channel where these tributaries affect it. This must mostly come from the Thibetan plateau; but the particular drainage area which supplies it is problematical; though there is reason to suppose it is the Sanpo valley of Great Thibet. So far as appears, floods have been felt in this upper part of the Burmese valley and at Mandalay in every year when they have existed in the delta. A flood discharge from the plateau would be very much moderated by inundating the plains above the Mogoung river, and would hardly cause arise above the banks at Mandalay unless it were supplemented by an abundant supply from this northern region of the Burmese basin. It has been proved from the dimensions of the upper tributary channels in the lower plains that these could not possibly fill the Irrrwaddy channel; and though greater floods than these can carry issue in exceptional circumstances from the defiles, like on the occasion of the deluge in the Taping valley in August 1868, all the excess beyond their capacity to carry is spread over the plains and retained there till the lowering of the Irrawaddy flood permits it to drain off. These channels therefore indicate truly *the rate* of contribution of the upper tributaries to the Irrawaddy.

Conditions requisite to great flood discharge in the lower part of the channel.

54. It seems an indispensable condition to a flood at Mandalay that both the Thibetan supply and the north Burman supply should be abundant. And though a flood at Mandalay has invariably preceded the floods on record in the delta; and no floods are known to have occurred at the one place and not in the other; it is clear that a flood at Mandalay could not cause one in the delta, unless combined with abundant accessions in the lower parts of the channel. At Saiktha the ordinary floods reach 1,200,000 cubic feet, the great flood of 1877 reached 2,000,000 cubic feet per second. One third to one half more than exists in the channel at Mandalay must be added in the interval to keep it at a corresponding height. The examination of the basins of the lower tributaries and of the central and lower part of the valley above Magwe proved that all these may be considered together, as being homogeneous in their action on the floods. The combined area comprises the greater part of the Burmese Irrawaddy basin, 70,000 square miles out of 125,000. By the configuration of the minor valleys and by the masses of permeable strata interposing between the impermeable and steep mountain gathering grounds of the floods and the river, these are moderated, and delivered to the Irrawaddy channel in a regular and even flow which, considering the great extent of country and the mass of water concerned, is of the utmost importance to the lower parts of the valley. The amount of water contributed by this region to the channel must from its steadiness tend to perpetuate the condition of flood or low water existing in the channel at Mandalay.

The importance of the hilly land above the delta in producing floods.

55. The third region consists of the whole of the lower part of the basin comprising some 15,000 or 20,000 square miles where the hill torrents throw such water as they receive into the river channel immediately, without the interposition of moderating agencies on a large scale. The rainfall over this part is, fortunately, not heavy, and appears generally to be regularly distributed. Otherwise from the closing in of the steep partially permeable hills on to the river channel from Maloon to Myanoung, comparatively short rainfalls, if as heavy as in the delta, would have most disastrous effects upon the river channel below. It is important therefore to ascertain on what conditions the distribution of the rain depends.

The rainfall records for British Burma.

56. The rainfall registers for the whole of the stations regularly observed in British Burma are given in Appendix III. Most of these have only been obtained for the years since 1870; but Moulmein is complete since 1850; Akyab has 1850 and 1851, and then a gap to 1860, while Sandoway is the only other

station the records of which are given earlier than 1870. The Aracan coast stations of Akyab, Kyouk-phyoo and Sandoway, form a distinct group lying close to the sea on the east side of the Bay of Bengal. With these the Chittagong records can be advantageously combined; as it lies on the same coast, and the branch of the south-west monsoon current which supplies the drainage to the main basin of the Burmese valley of the Irrawaddy passes over the coast between Chittagong and Sandoway, a distance of some 400 miles. Closely allied to these stations and forming a sub-group connected with them, are Prome and Thayetmyo, lying in the narrow and hilly neck of the basin above the delta; and receiving their rainfall from the same current as the foregoing; but it has passed over the Aracan Yoma, where it rises an average of 4000 feet. Sandoway in particular is on the same line with them. They are distant from 70 to 80 miles from the sea in the direction of the wind, and are respectively 250 and 290 miles from the mouth of the river.

The Aracan and Irrawaddy groups of stations.

57. The delta stations, Bassein, Henzadah and Rangoon are grouped together, for though Bassein and Henzadah are situated where they receive a portion of the rainfall across the Yoma range, being about 25 and 60 miles from the sea on this side, the range is considerably lower here, not rising generally above 2,000 feet; and they also receive a portion of their supply direct and uninterruptedly from the sea fronting the delta to the south. Bassein is 90 miles from the sea on the right arm of the Irrawaddy; Henzadah 120 on the main channel; and Rangoon over 20 on the left arm of the delta. Allied with this is the sub-group of Tounghoo and Shoaygheen, towns on the Sittang; the former 150, the latter abont 80 miles from the gulf of Martaban. The same branch of the south westerly current that flows over Bassein and Rangoon, supplies the rainfall of Tounghoo and Shoaygheen, with some interruption from the southern Pegu Yoma. A third group consisting of Moulmein, Tavoy and Mergui on the western coast of the Malay Peninsula is available for comparison, though lying out of the track of the principal rain bearing winds bound for the Irrawaddy valley.

The Delta Stations.

The Tenasserim Stations.

58. The average rainfall for the number of years given is shown in the accompanying Table for the stations on the eastern side of the Bay of Bengal, arranged in the groups and sub-groups above noted :—

Table of average rainfall.

Table V.

Name of Station.	Latitude.	Longitude.	No. of years	January.	February.	March.	April.	May.	June.	July.	August.	September	October.	November	December.	Year.
1st Group. Stations in path of Branch of S. W. Monsoon carrying rain towards Irrawaddy Valley. 1st Sub-Group. Stations on Aracan Coast.																
Chittagong ...	22°11'	91°50'	18-20	0·56	1·45	1·36	4·58	9·02	22·28	22·43	22·45	13·30	6·09	1·63	0·37	105·61
Akyab ...	20°8'	92°57'	19-20	0·13	0·21	0·45	1·18	13·32	47·30	48·29	36·41	26·06	11·83	3·85	0·20	189·23
Kyouk-phyoo ...	19°22'	93°35'	12	0·11	0·08	0·45	1.05	9·92	39·41	45·19	39·02	20·85	9·63	4·95	0·12	170·76
Sandoway ...	18°23	94°24'	16-17	0·07	0·09	0·20	0 78	15·04	53·07	59·95	49·63	24·91	12·23	2·52	0·09	218·58
2nd Sub-Group. Stations in Irrawaddy Basin.																
Thayetmyo ...	19°20'	95°14'	8	0·00	0·04	0·13	0·59	6·71	8·30	9·18	10·24	8·72	5·40	1·72	0·01	51·04
Prome ...	18°50'	95°13'	8	0·00	0·00	0·01	0·84	6·17	9·69	9·37	14·46	7·72	6·46	1·74	0·00	56·46
2nd Group. Stations in path of Branch of S. W. Monsoon passing over the Irrawaddy Delta. 1st Sub-Group. Stations in the Delta.																
Henzadah ...	17°39'	95°30'	7	0·11	0·00	0 00	0·56	6·13	15·74	19·39	16·96	11·02	4·67	2·29	0·00	76·87
Bassein ..	16°47'	94°47'	8	0·25	0·00	0·14	1·02	7·53	16·22	26·28	21·81	14·50	7·27	2·56	0·03	97·61
Rangoon ...	16°46'	96°12'	8	0·06	0·06	0·08	1·69	12·27	19·82	21·67	18·56	15·61	9·06	2·83	0·00	101·71
2nd Sub-Group. Stations in the Sittang Valley.																
Tounghoo ...	18°56'	96°34'	8	0·00	0·00	0·04	0·98	6·99	11·93	16·94	17·32	10·65	8·03	1·49	0·06	74·43
Shoaygheen ...	17°54'	96°55'	9	0·01	0·42	0·66	1·61	14·76	35·37	36·18	33·82	2·026	10·56	1·85	0·00	155·50
3rd. Group. Stations in path of Branch of S. W. Monsoon passing to the south of the Irrawaddy Valley. Martaban Group.																
Moulmein ...	16°39'	97°40'	2·8	0·00	0·04	0·14	3·13	21·13	38·75	43·72	43·89	31·51	8·13	0·94	0·01	191·34
Tavoy ...	1°45'	98°19'	20·21	0·13	0·71	0·58	3·42	18·12	39·03	44·81	42·66	33·96	10·03	1·90	0·12	195·47
Mergui ...	12°20'	98°36'	13·14	0·41	1·34	1·80	4·94	17·23	28·34	29·25	28·05	24·41	12·57	2·35	0·46	151·15
4th Group. Stations in path of Central Branch S. W. Monsoon passing to Thibetan Plateau. Assam-Thibet Group.																
Darjeeling height 6,912 feet. ...	27° 3'	88°18'	14·17	0·50	1·09	1·42	4·27	6·66	25·85	29·27	25·51	16·99	7·34	0·17	0·18	119·25
Sylhet ...	24°52'	91°56'	18·22	0·49	0·54	5·29	13·98	22·13	31·85	26·14	24·02	19·22	8·33	0·66	0·15	153·80

(1.) This Table has been corrected by the latest Report issued from the Meteorological Office, that for 1877. It was originally drawn up from the 1876 Report; and some of the subsequent Tables are based upon the original.

To the before mentioned groups, another containing Darjeeling and Sylhet has been added to permit a comparison with the principal branch of the monsoon directed to the plateau of Thibet. The former place is on a spur of the Sikhim Himalayas, nearly 7,000 feet above the sea. It lies in the path of the monsoon towards Lassa which comes without interruption from the Bay. Sylhet is on the plains of southern Assam, immediately in front of Cherrapoonjee ; and, if the monsoon wind retains its S. W. direction after passing over the Khasi hills and Himalayas, the same stream should pass over the lower end and eastern tributaries of the Sanpo valley. It would have been desirable to incorporate with the Irrawaddy basin sub-group the station of Munipoor, but Pemberton gives only the yearly, not the monthly, averages of rainfall.

Assam and Himalayan Stations.

59. The yearly averages show that the stations of Akyab, Kyouk-phyoo and Sandoway have nearly the same rainfall, of, approximately, 200 inches. Sandoway lies in the path of the winds carrying rain to Prome and Thayetmyo. The intervening Aracan Yoma, from 3,000 to 4,000 feet in height, intercepts the greater part of the rain, and reduces the fall in the valley to 51 inches and 56, compared with that at the coast of 218 inches. Akyab and Kyouk-phyoo lie directly across the current which traverses the arid region about Pagan, and the sea-coast falls of 178 and 204 inches are reduced to less than 10 inches in the centre of the zone. The Aracan Yoma is here somewhat higher than opposite Prome. It averages over one mile in height ; and intercepts therefore a much greater quantity of vapour from the air than at the more southern stations. Though the arid and unculturable country is not of very great extent, everything seems to indicate that this is simply an intensified condition of the state of things existing over the whole of the central part of the Irrawaddy valley. A comparatively small rainfall is proved to exist by the statements of travellers over the whole of the western part of the valley from Munipoor to Prome ; and it is known that Mandalay and the plain country beyond on the east side have also a comparitively small rainfall. At Munipoor the rainfall for four years averaged 48·33 inches. It is probable that, excepting the basins of the northeast tributaries, the rainfall of the Irrawaddy basin nowhere averages much above 50 inches ; and that the greater part of the valley plains average much below that amount.

Characteristics of the different averages.

60. Chittagong, which lies nearly S. W. from Munipoor, has a rainfall of only one-half the average of the three Aracan Stations. It corresponds in this with Noacally, which lies about 50 miles N. W. on the same plains at the head of the Bay ; and it is noticeable that none of the stations, as far west as Calcutta, in similar positions, reach the great average of Akyab. Sylhet, which lies much further from the sea and due north of Chittagong, has a rainfall of 153 inches, against the 105 of the latter. And Cherrapoonjee, some 30 miles further north, but standing at an elevation of 4,125 feet above the sea on the Khasi hills, receives an average rainfall of 600 inches yearly. The Assam plains to the north of these hills, which like the Aracan Yoma average about one mile in height, have a rainfall of 80, 90 and 100 inches yearly, showing the presence of a vast amount of vapour in the air, even after the immense precipitation on the Khasi hills. There must therefore be a great difference in the depth and strength of the Assam and Aracan branches of the monsoon. The former appears to have the vapour distributed through it evenly to an immense depth ; and to be already rising to the plateau with its burden. The layers of air nearly a mile high, are nearer saturation than the lower ones. In the Aracan branch the lower currents appear the nearest to saturation. At one mile in height it is nearly denuded of the greater part of its vapour, and must be a much weaker and shallower stream than the Assam current. It is not, however, so entirely spoiled of its moisture by the Aracan Yoma as the diminished fall at Pagan would indicate. The immense precipitation on the Aracan side releases the heat energy that held up

The Assam-Thibet and the Aracan-Irrawaddy branches of the monsoon.

the vapour. This warms the neighbouring air, which rises over the hill crests, and when compelled to fall into the Irrawaddy valley becomes still hotter and relatively dryer. On again ascending over the the eastern mountains it cools, and parts with more moisture to their slopes and crests, and produces the greater rainfall of the Shan plateau and Yoma.

The delta and Tenasserim branches of the monsoon.

61. The stations of the delta, and of the Sittang valley, have on the average about half the annual rainfall of the Aracan group and of the Tenasserim group, which is nearly equal to that of Aracan. The influence of the Aracan Yoma is seen at Henzadah, where the fall is 76 inches, against 98 at Bassein, and 102 at Rangoon. And the Pegu Yoma reduces the Tounghoo rainfall to 74 inches, against 152 at Shoaygheen, which is open to the sea breezes in front, and is backed by high hills on the east. This last feature it shares with all the Aracan and Tenasserim stations; and if we can suppose that the presence of high hills cause a greater rainfall on the low lands in front than on plains not so situated, we may infer that the whole monsoon atmospheric current from northern Aracan to the south of Tenasserim is uniform in depth, in strength, and in vapour tension on the average of a number of years. Any deviations from the mean rainfall at each group of stations must indicate a general alteration in the uniformity of the branches of this current. Unfortunately, the number of years for which observations are available for all the stations is too small to draw any general deductions.

Comparison of yearly rainfalls.

62. The only Burmese stations for which the annual rainfall records exceed 8 in number are Akyab 16 to 18, Sandoway 17, and Moulmein 28. The greatest rainfall recorded at Moulmein was 279 inches in 1865; the next greatest was 263 in 1863. The least were in 1850 and 1852 when it averaged 124 inches in each year. The register is given for Akyab for 1850, when the largest rainfall but one on record 254 inches fell. The monthly averages show that the principal deficiency occurred in Moulmein in August of that year, when 30 inches below the usual quantity was received. In Akyab the greatest excess of 22 inches above the average fell in the same month. This indicates a divergence of the Burmese monsoon current from south to north of its usual path. The year of great rainfall at Moulmein, 1865, was one of average fall at Akyab; but in August of that year there was a deficiency of 12 inches here, while Moulmein received an excess of 33 inches in the month. This suggests a divergence of the monsoon current temporarily southwards. More complete records would have permitted he study of the divergence in more detail.

The great flood years on the Irrawaddy

63 The years of great flood on the Irrawaddy are 1868, 1871, 1875, and 1877; the gauge at Myanoung showing an increased elevation of the river surface there in the order of the years given. Table III indicates that at Mandalay the flood of 1875 was higher than that of 1877; and it is known to have been higher than those of 1871 and 1868. The measurements of the discharge prove that the flood of 1871, though not so acute in its rise as those of 1875 and 1877, brought down a larger quantity of water for the whole year, or 482 against 466 billion tons. Exceptional opportunities for personal observations of the flood of 1868 in the upper parts of the basin were afforded to the different members of the expeditionary party to Yunan that year. From these it was proved that four conditions concurred to produce that flood, which existed in the whole length of the river channel. Firstly, the channel at Bhamo was nearly filled and the country above the Tshenbo defile flooded by an abnormal discharge from Thibet. Secondly, the northern tributaries, particularly the Taping and Shweylee, were in abundant flood, and transferred the flooded condition of the Irrawaddy from Bhamo to Mandalay. As a third condition required to perpetuate this state of

The Flood of 1868.

flood through the open valley from Mandalay to Maloon, the southern tributaries contributed a steady and abundant supply. And, finally, the torrent streams in the narrow neck of the basin from Maloon to Saiktha kept up the acute rise of the flood wave passing down the river. The only observations of rainfall for that year show that Moulmein had a fall of 20 inches above the average; Akyab 11 inches; and Sandoway 35. The want of further observations makes itself felt here. The ones given, however, prove that the whole Burmese monsoon current was in that year above its average strength. It would be desirable to know the condition of the current ascending the plateau in that year.

The rainfall of the flood year 1871.

64. The rainfall records for 1871 for the Burmese stations are complete. The differences of rainfall in this year from the average are given in the accompanying Table. plus signs show an excess, minus signs a deficiency of so many inches:—

Table VI.

TABLE OF DIFFERENCES OF RAINFALL FOR THE YEAR 1871 AND AVERAGES.

	Name of Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
ARACAN GROUP.	Akyab ...	—0·13	—0·21	+0·35	—1·18	+10·28	+18·20	—3·19	—9·31	—3·66	+2·77	—3·85	+0·50	+10·57
	Kyouk-phyoo ...	—0·11	—0·08	+0·97	—1·05	+9·98	+11·29	+6·41	—7·72	—1·05	+7·87	—4·25	+0·08	+22·34
	Sandoway ...	—0·07	—0·09	+1·00	—0·78	+13·06	+11·53	+0·35	— 2 13	—6·11	—2·83	—2·52	—0 09	+11·32
	Thayetmyo ...	—0·00	—0·04	—0·13	—0·39	+1·69	—0·60	+0·42	+0·46	+3·28	—0·10	—0·02	—0·01	+3·56
	Prome ...	—0·00	—0·00	+0·09	—0·84	+7·23	+4·51	—1·67	—7·88	+1·78	+4·94	—1·74	—0·00	+6·44
DELTA GROUP.	Henzadah ...	—0·11	—0·00	—0·00	—0·56	+4·17	+10·26	—3·09	—2·76	+1·98	+2·33	—2·29	—0·00	+9·93
	Bassein ...	—0·25	—0·00	—0·14	—0·72	+3·77	+9·78	—8·98	—7·41	—0·50	+0·83	—1·86	+0·17	+4·21
	Rangoon ...	—0·06	—0·06	+0·42	—1·69	+14·93	+12·58	+5·53	+8·74	+3·59	+0·54	—2·83	—0·00	+41·69
	Tounghoo ...	—0·00	—0·00	+0·26	—0·98	+8·01	+8·17	+2·16	+1·08	+6·35	+2·27	—1·39	—0·06	+25·87
	Shwegheen ...	—0·01	—0·42	+0 64	+0·29	+15·34	—1·87	+9·22	+8·78	+10·24	+5·24	—1·05	—0·00	+46·40
SOUTHERN GROUP.	Maulmain ...	—0·00	—0·14	—0·14	+0·12	+14·87	+16·70	—0·32	+7·61	+7·64	+8·97	—0·94	—0·01	+54·51
	Tavoy ...	—0·13	+6·29	+0·72	—2·12	+11·98	—0·53	—0·41	—8·96	+25·34	+4·17	—1·90	—0·12	+34·43
	Mergui ...	—0·41	+4·16	+8·20	—1·34	+7·37	+16·96	— 5·35	6·55	+5·69	+1·13	—2·25	—0·46	+43·25

It is apparent from this Table that the year 1871 was, on the whole, one of exceptional rainfall throughout Burma, eleven out of thirteen stations showing an excess. Akyab and Bassein are very slightly below it. No data are available for

the more northern stations beyond Burma. On examining the monthly averages it is apparent that the whole of the stations record the principal excess in May and June, indicating a general increase of strength in all the width of the Burmese monsoon. In July there is a falling off apparent ; some stations being slightly below, and some above the average in each group. In August the Aracan group, with the Irrawaddy basin station of Prome, and the delta stations of Bassein and Henzadah fall decidedly below the average ; while the more southern and eastern stations as a rule are above it. The southern branch of the monsoon has apparently increased in strength at the expense of the Aracan branch. In September the same tendency presents itself, but in a less degree.

The Myanoung gauge diagram for the 1871 flood.

65. Turning now to the diagram of gauge readings at Myanoung (Plate III) near the head of the delta, we can see the progress of the flood in the river during the same period ; while the diagram of discharges (Plate IV), and measurements of the water discharged will aid in the discussion. The gauge reading shows that the rise at Myanoung in May was about the average ; but early in June the flood attained a higher level than in any other year. It fell again slightly ; but went up to 30·33 feet on 30th June. It fell 4½ feet by the 4th July, and then continued to rise steadily till 6th August, when the gauge read 39·25 feet ; or 1·66 feet above the highest flood recorded, that of 1868. It continued at this level for two days, then fell 9 feet by the 22nd ; and rose again to 38·17 feet on the 10th September. It then fell regularly through October. It is to be remarked that the flood of September 10th is higher than the highest flood of 1868 by 0·58 feet ; being thus very exceptional in its nature.

Flood discharge in 1871.

66. The discharges give accurately the measure of these flood variations. The average flood discharge for each month and for the whole year is given in Table VII. The differences between these averages and the monthly and yearly discharges for 1871 are given in the accompanying Table.

Table VII.

Differences of Monthly Discharges of Irrawaddy river at Myanoung. FOR THE YEAR 1871 *And the average discharge.*	METRE-TONS.
January.	+147,186,900
February.	—194,196,620
March.	+882,702,305
April.	+980,640,925
May.	—857,157,707
June.	+12,322,144,778
July.	+8,418,103,551
August.	+7,024,251,909
September.	+17,379,052,070
October.	—3,695,750,681
November.	+11,444,993,456
December.	+3,023,886,653
Year.	+56,875,858,479

Except February, March and October every month shows an increased discharge, the total for the year amounting to nearly 57 billion tons above the average, a larger amonnt than in any other year. The deficiency in May is remarkable. In that month every station in that Province records a higher rainfall than usual ; those stations in particular which lie in the path of the monsoon towards the Irrawaddy basin being very high. Akyab and Sandoway give each 13 inches ; Kyouk-phyoo 10 and Prome 7 inches above the average fall for the month. In each case it is almost double the usual supply. It is unfortunate that we cannot compare this with the stations in the path of the monsoon stream to the plateau. No doubt the upper parts of the river in Thibet received a smaller supply of rain than usual. The excess fall in the Burmese valley would be absorbed in saturating the permeable strata of the plains of the tributaries and of

the main river. The June excess fall would then come down on prepared ground and be more readily transmitted to the main channel; but the quick rise, and the great excess of discharge for that month of 12 billion cubic metres must have been assisted by a strengthening of the northerly branch of the monsoon, carrying a larger supply to the Thibetan sources. There is a total want of correspondence between the excess discharge of the river in July, in August, and in September, and the available rainfall records; and these, so far as they go, leave the difficulty inexplicable. It is possible that the rainfall of May and June may have been stored up in the permeable strata of the basin, to drain out leisurely in July and August. But no equable discharge of this kind could cause a high flood of itself in any part of the main channel. At the utmost it perpetuates through a great length of channel whatever stage of high water it finds at its influx. The July rainfall was below the average at all the stations of the delta and on the Aracan coast. The discharge for July is 8 billion tons above the average. The rainfall for August was below; the discharge for August 7 billion tons above the average, The extreme high rise and gently rounded character of the flood wave prove that it came from an immense distance; and was of great magnitude. The character of an acute flood produced by an abnormal rainfall in the neck of the basin supervening on an already flooded channel is seen in the diagram for 1877; and the shape of the curve always gives a correct general indication of the origin of the flood. This is seen also in the September rise for 1871, when the enormous total of 94½ billion tons, or 17 above the mean for that month were discharged. The Aracan coast stations had a rainfall below the average, but Prome and Thayetmyo were somewhat above. This sufficed to add a sharp rise to the curve of the flood wave from the 8th to the 12th of September; but changed very little the immense mass of the whole wave which passed from 23rd August to 22nd September; as shown by the slight influence a much larger fall in the same part had in May. We are compelled to recur to the supposition that while the southern branch of the Burmese monsoon became stronger, and the Aracan branch weaker, the more northerly branch which feeds the Thibetan sources of the Irrawaddy acquired an abnormal strength. Had we records of the river at Bhamo and Mandalay, with indications of the condition of the Assam branch of the monsoon ascending to the plateau, no doubt a distinct co-relation between the different series of facts could be traced. As such information may be made available for the future, without extra expense, by the agencies already existing, it is hoped interest will be made to secure this being done.

The 1875 flood.

67. It is possible to follow the phases of the 1875 flood with more precision. The Meteorological Report for India for 1875 furnishes details additional to those possessed for previous years. And as this extraordinary flood may be taken as a typical one, the meteorological data available in the Province are given for this year in Appendix V; with those for 1876, a year of ordinary flood. The barometrical records are incorrect; and are left out. But the rainfall, the hygrometric and the wind records are useful. The averages are given for each week; and are not directly comparable with the monthly ones; but will serve for present purposes.

68. The differences between the monthly rainfalls for 1875 and the averages are given in the following Table :—

Rainfall in 1875

Table VIII.

1875.

Name of Station.	January.	February.	March.	April.	May.	June.	July.	August.	September	October.	November	December.	Year.
Chittagong...	+5·12	+1·45	—0·11	+1·65	—2·05	+10·74	+5·43	+16·18	+0·53	+4·13	+1·63	+0·37	+30·11.
Akyab ...	—0·13	+0·21	—0·45	+1·03	0·00	—6·80	+4·34	—15·81	—5·26	+9·43	+3·85	+0·20	—38·83
Kyouk-phyoo	—0·01	+0·08	+1·57	+3·05	—4·68	+22·59	+23·91	—8·02	+5·45	+0·23	+3·05	+0·12	+49·74
Sandoway ...	+0·43	+0·09	0·00	+1·72	—5·24	—6·17	+21·85	—14·13	+10·69	+5·07	+2·22	+0·09	+11·82
Thayetmyo...	0·00	+0·04	—0·13	+2·91	—0·11	—0·20	+7·02	—2·14	+2·08	+0·20	+1·42	0·01	+7·76
Prome ...	0·00	0·00	—0·01	+1·66	—3·17	—1·99	+2·13	—8·26	—1·72	+0·54	+1·74	+0·00	—12·56
Henzadah ...	—0·11	0 00	0·00	+3·74	+4·13	+0 40	+13·45	+5·70	+1·33	+0·66	+0·92	0·00	+28·11
Bassein ...	+1·67	0 00	—0·14	+0·90	+2·75	+8·05	+2·33	—6·53	+7·59	+3·40	+1·54	+0·03	+13·79
Rangoon ...	—0·06	+0·06	—0·08	+3·21	+4·63	—4·32	+4·07	—9·06	—7·71	+5·96	+1·07	0·00	—22·41
Tounghoo ...	0·00	0·00	—0·04	+4·62	—2·17	—2·81	+5·54	+9·71	—0·15	+4·97	—1·49	+0·44	+18·62
Shoa-ygheen.	—0·01	+0·42	—0·66	—1·61	+2·54	+5·93	+19·52	—11·82	+5·84	+2·26	—0·45	0·00	+16·60
Moulmein ...	0·00	+0·04	—0·04	+2·52	—3·93	+14·20	+0·62	—4·74	+23·29	+0·92	+1·81	+0·01	+33·21
Tavoy ...	—0·13	+0·66	—0·58	+2·98	—7·74	+1·85	+19·09	—0·61	+9·69	+10·14	—0·86	+0·12	+34·43
Mergui ...	—0·31	+1·24	—1·78	—3·74	—0·95	+1·84	+1·37	—5·40	—8·46	+1·08	—1·13	+0·43	—19·15
Darjeeling ...	+1·18	+0·24	+0·12	—1·56	+1·26	+4·26	+1·81	+5·57	—5·55	+7·29	+0·17	+0·15	—4·08
Sylhet ...	+1·11	+0·33	+6·86	+8·94	—0·97	+14·16	+1·83	+6·00	—0·27	+5·75	+0·66	+0·07	+29·99

69. In March the rainfall is about the average ; in April there is a general excess, and in May a general deficiency. The most exceptional departures from the average are the heavy excess falls in Sylhet of 6·84 inches in April and 7·92 in May, denoting unusual strength in the central current of the monsoon towards the plateau. The winds in April prevailed from the S. S.W., and S.E. at Darjeeling, Chittagong and Akyab, and had an easterly direction in Assam. In Burma the general direction was from N.E, and N.W. with occasional admixtures from the south. In April S.W. winds predominated. The river gauge records for Myanoung, as shown in the diagram (Plate III), prove an exceptional rise of the river during April and May, which can be accounted for by the heavy rainfall of April over the whole basin of the Irrawaddy. It came down to the delta in two waves ; the first towards the end of April from the nearer parts of the basin ; the second reaching a climax on 12th May. From the acute form of the latter wave it would appear that local rainfalls in the neck of the basin were added to the mass of the wave coming from northern Burma and Thibet. The amounts of water discharged at Myanoung were above the average for the whole dry weather season, the excess reaching $9\frac{1}{4}$ billion tons in May, or 44 per cent. above the mean for that month. As, except in April, the majority of the stations in Burma and on the coast of the Bay of Bengal show a deficiency, while the Assam stream of the monsoon to the Sanpo valley is in great strength, it is probable the excess supply comes from that source.

The flood wave at Myanoung.

Daily rainfall for June, July, and August 1875.

70. The great flood waves of the year in June, July and August present such abnormal features that the daily rainfalls for those months at the Burmese stations are given for comparison in Table IX. The average rainfalls for June and July present some anomalies. All the Aracan and Irrawaddy stations except Kyouk-phyoo are in deficiency in June; Akyab by 11·85 inches, Sandoway by 6·16 inches. Kyouk-phyoo has an excess fall of 23·63 inches for the month, or 61 per cent above the average. Syhlet and Chittagong on the path of the Thibetan monsoon current are respectively 43 and 45 per cent above the average for the month. The Myanoung gauge diagram shows the river to have risen gently from the 5th to the 12th June, about 2 feet in a week. Then commenced the most remarkable rise on record. On the 12th the river surface marked 10·67 feet on the gauge; on the 13th, 12·25 feet; on the 14th, 16·06 feet; on the 15th, 20·58 feet, a rise of 4·52 feet in 24 hours, with a further rise next day of 2·34 feet. The corresponding discharges are for the 12th June 690 million tons per day; for the 14th 1,086 millions; for the 15th 1,481 millions, or an addition of about 400 millions tons in one day. The rise continued till the 16th July; when the discharge was 3,426 millon tons per day; and the gauge reading 36·25 feet at Myanoung. A fall of 5 feet by the 31st July terminated this flood wave, and prepared for the greatest rise of the year. From the daily rainfall records it appears that heavy rain commenced on the 10th over the whole breadth of the region extending from Prome and Thyetmyo northwards to Akyab. Whether it extended further north or not cannot be learned in the absence of the Assam and Bengal stations detailed records. No excessive falls are recorded in the earlier part of this time, the heaviest being 4·14 inches for Akyab on the 13th, and 4 for Kyouk-phyoo on the 14th June. But towards the end of the month very heavy falls are recorded; principally at the more southern stations. Thus 5·8 inches, 4·30 inches and 9·30 inches are recorded at Kyouk-phyoo on the 21st, 22nd and 24th June; and 5 5, 5·4, 7·22 and 5·6 on the 22nd, 24th, 26th and 27th June at Sandoway. The rain bearing current appears to have travelled southwards. These exceptional rainfalls were accompanied by ordinarily heavy ones on other days; and were followed by similar weather in July.

Table IX.

71. *Daily Rainfall for June* 1875.

Day.	Bassein.	Henzadah.	Myanoung.	Prome.	Thayetmyo.	Sandoway.	Kyouk-phyoo.	Akyab.
1	0·88	0·57	0·00	0·00	0·00	0·33	2·00	0·01
2	0·25	0·07	0·10	0·06	0·00	0·27	0·00	0·88
3	0·46	0·25	0·40	0·72	1·68	0·00	0·00	0·15
4	0·81	0·20	0·50	0·14	0·48	1·11	0·80	0·44
5	0·15	0·76	0·30	0·00	0·26	2·03	2·00	1·07
6	1·16	0·16	0·30	0·28	1·30	0·47	0·80	0·52
7	0·29	0·68	0·30	0·15	0·56	0·00	0·10	0·34
8	0·23	0·11	0·00	0·12	0·41	0·00	0·50	1·27
9	1·05	0·72	0·00	0·00	0·00	0·20	0·10	0·66
10	0·29	0·56	0·00	0·08	0·84	1·60	1·50	2·28
11	0·07	0·03	0·10	1·19	0·29	1·18	3·20	3·24
12	0·34	0·02	0·50	1·07	0·12	0·70	3·80	0·97
13	0·23	0·33	0·00	0·09	0·16	3·91	2·30	4·14
14	0·72	0·11	0·00	0·08	0·00	2·80	4·00	2·32
15	1·35	0·43	0·00	0·09	0·00	1·12	3·40	0·74
16	0·44	0·00	0·00	0·33	0·34	1·57	1·00	1·43
17	0·48	0·46	0·20	0·14	0·00	1·74	1·80	1·15
18	0·58	0·43	0·00	0·07	0·22	0·58	1·80	0·87
19	0·00	0·77	0·20	0·00	0·00	0·33	1·40	2·03
20	0·00	0·00	0·30	0·17	0·00	2·60	2·00	0·79
21	3·00	1·65	0·10	0·04	0·00	2·42	5·80	1·24
22	1·39	0·50	0·00	0·00	0·60	5·50	4·30	4·54
23	0·88	0·78	1·30	0·37	0·36	3·62	3·50	3·86
24	0·01	0·56	0·16	1·12	0·40	5·40	3·50	3·87
25	0·015	2·06	0·00	4·00	0·26	0·50	1·80	1·46
26	0·34	0·07	0·00	0·00	0·12	7·22	3·80	1·50
27	4·04	0·17	0·60	0·26	0·22	5·60	3·50	4·64
28	0·90	2·37	1·30	1·12	1·98	4·83	4·50	2·75
29	0·27	1·26	0·00	0·07	0·12	0·76	0·50	0·52
30	3·65	9·06	0·00	0·00	0·72	0·67	1·00	1·16
Total	24·27	16·14	6·60	11·70	11·44	59·06	70·50	50·64

Daily Rainfall for July 1875.

Day.	Bassein.	Henzadah.	Myanoung.	Prome.	Thayetmyo.	Sandoway.	Kyouk-phyoo.	Akyab.
1	1·20	0·10	0·10	0·00	0·00	0·26	0·20	0·23
2	0·91	0·15	0·60	0·32	0·35	2·78	1·50	0·00
3	2·12	1·01	0·30	0·15	1·20	4·27	0·50	0·60
4	0·70	1·96	0·10	0·20	0·16	3·72	9·70	2·07
5	6·47	0·07	0·00	0·10	0·00	0·37	0·60	0·83
6	0·005	0·98	0·00	0·00	0·00	0·00	0·20	0·20
7	0·70	0·63	0·20	0·00	0·00	0·00	0·30	0·00
8	0·20	0·11	0·00	0·20	0·00	0·20	0·60	0·00
9	0·135	0·26	0·60	0·44	0·10	4·36	2·00	0·87
10	0·39	0·43	0·20	0·10	0·12	2·64	1·20	0·97
11	0·16	0·16	0·00	0·24	0·18	2·66	1·50	4·38
12	0·35	0·28	0·80	1·31	0·82	6·74	1·90	4·11
13	0·58	3·63	1·10	0·67	0·79	2·41	8·00	5·30
14	0·46	1·70	0·20	0·58	1·94	2·96	0·50	1·81
15	0·03	1·05	0·10	0·70	0·18	1·70	0·30	2·02
16	0·47	0·03	1·10	0·31	0·18	2·69	0·50	0·05
17	0·47	0·07	0·30	0·00	1·90	0·29	0·10	0·00
18	2·795	0·10	0·00	0·50	0·00	1·22	0·30	0·00
19	1·89	0·43	0·40	0·46	0·30	1·22	1·80	0·40
20	1·19	0·55	0·20	0·20	1·54	3·56	1·40	0·60
21	2·28	0·87	0·30	0·22	0·10	2·00	2·40	3·46
22	1·235	0·92	0·20	0·11	0·60	3·68	1·50	1·48
23	0·71	2·03	0·40	0·78	1·34	6·52	1·50	0·58
24	1·86	2·95	1·00	0·28	0·04	2·42	2·50	0·16
25	0·91	2·73	0·80	0·18	0·70	2·68	3·50	0·59
26	0·01	2·06	0·50	1·30	0·30	1·61	2·60	1·61
27	0·105	2·80	0·40	0·20	0·04	0·00	2·50	0·45
28	0·65	0·15	1·60	1·48	0·64	1·22	2·60	656
29	0·07	2·90	0·10	0·26	0·40	0·63	0·50	1·58
30	0·19	0·25	0·90	0·32	0·68	1·08	1·00	3·40
31	1·33	1·48	0·60	0·45	0·66	0·00	2·40	4·49
Total	24·57	32·84	13·10	11·76	15·26	65·89	55·10	48·80

Daily Rainfall for August 1875.

Day	Bassein.	Henzadah.	Myanoung.	Prome.	Thayetmyo.	Sandoway.	Kyouk-phyoo.	Akyab.
1	0·00	1·31	0·00	0·26	0·64	3·33	0·80	4·44
2	0·28	0·61	0·20	0·24	0·28	2·90	0·60	1·76
3	0·13	0·47	0·00	0·00	0·00	1·30	0·80	0·60
4	1·21	0·08	0·20	0·36	0·00	1·80	3·50	2·32
5	0·16	0·16	0·00	0·44	1·91	0·10	0·30	0·88
6	0·385	1·75	0·80	0·10	0·81	0·20	0·10	0·58
7	0·09	0·22	0·70	0·80	0·26	0·37	0·00	0·10
8	0·31	2·05	0·50	0·00	0·00	0·80	0·00	0·04
9	0·145	0·43	0·10	0·45	0·30	0·27	0·50	0·06
10	1·34	3·11	3·20	0·21	0·16	2·96	0·00	0·34
11	0·08	3·44	0·20	0·37	0·30	1·56	2·00	0·00
12	0·92	0·02	0·10	0·21	0·42	1·88	1·00	1·52
13	1·22	0·98	0·10	0·16	0·14	2·40	3·80	0·55
14	0·71	0·33	0·20	0·50	0·18	0·70	0·80	2·44
15	2·19	0·05	0·00	0·50	0·10	2·60	1·00	0·8
16	0·89	0·74	0·16	0·76	0·50	1·55	1·00	0·20
17	1·16	0·40	1·30	0·00	0·00	2·65	3·00	0·67
18	0·36	0·15	0·10	0·20	0·22	0·35	1·00	0·40
19	0·05	0·17	0·60	0·00	0·14	0·30	1·00	1·52
20	0·09	1·74	0·20	0·67	0·00	1·71	1·50	0·19
21	0·39	0·06	0·20	0·00	0·50	3·51	2·50	0·72
22	0·00	1·62	0·50	0·30	0·00	0·27	2·00	1·02
23	0·00	0·26	0·40	0·42	0·20	2·12	0·50	1·48
24	0·31	0·00	0·60	0·30	0·14	0·00	1·00	0·19
25	0·36	0·82	0·50	0·00	0·00	0·09	0·50	1·00
26	0·18	0·49	0·00	0·18	0·00	0·19	0·30	1·09
27	1·01	0·10	0·00	0·25	0·00	0·44	0·00	0·00
28	0·015	0·00	0·00	0·40	0·00	0·00	1·50	0·91
29	1·21	0·07	0·10	0·45	0·00	0·12	1·00	2·64
30	0·39	0·19	0·00	0·00	0·00	0·04	1·00	1·13
31	0·70	0·84	0·00	0·78	0·00	0·10	1·50	0·89
Total	15·285	22·66	10·90	9·31	7·30	36·61	34·50	30·46

72. The rainfall first mentioned of the 10th to 15th June seems to have been a mere prelude to the advent of a continuous heavy supply of rain over the whole Burmese valley of the Irrawaddy from the 20th June to the 4th of July, as evidenced by the falls at the Aracan Stations and at Prome and Thayetmyo. Kyouk-phyoo and Sandoway show excesses of nearly 22 inches at each place on the whole month of July; Thayetmyo 7 inches. It seems as though the rain-bearing current while flowing continuously in a direction from S. W. to N. E. over Burma. was in course of transference bodily from N. to S., both on the occasion of this fall and the last one. If the whole process of this transference could be traced by records of fall, through Assam, Thibet, and Upper and Lower Burma, it would probably serve to explain the causes and mode of formation of the greater floods of the Irrawaddy. After the midsummer solstice the heat and indraught centre of the monsoon tends to return southwards over the whole plateau; and the separate smaller centres of indraught peculiar to the Indian and Burmese Peninsulas in the changes of the monsoons are ready to break off from the principal one and resume their journey southwards. A sudden cooling of the principal indraught centre through an enormous precipitation of rain would be followed by the minor centres temporarily predominating and drawing the rain-bearing current to themselves. Each as it received the consequent downpour of rain would be cooled, and a lateral diversion of the air current take place. In the Burmese Peninsula this indraught centre would thus successively occupy all the points of the usual locus of travel from N. to S. and the heavy rainfall which commenced over the Sanpo valley would be transferred bodily over each succeeding part of the area of the basin through the northern tributary valleys, though the southern tributaries and the main valley of the Irrawaddy, to the neck of the basin, and finally to the delta.. The floods of the river travel in the same direction, and the rain supply thus coming down simultaneously with the upper floods, maintains the whole channel of the river in a state of acute flood. It is only in this way that the formation of the mass of the wave now considered can be accounted for from the rainfalls of the Burmese stations. The smaller wave, riding as it were on top of the main one from the 12th July to the 18th, must have been due to local showers somewhat distant from the delta, such as that passing over Sandoway on those days.

Probable process of formation of great flood wave.

73. Probably the greater part of this rainfall was stored up in the tributary valleys and plains of the Irrawaddy, and only reached the main channel at Myanoung in a moderated condition during the great flood of August. It is known, both from information received at the time, and from the exact figures given by Mr. Bain in Table III, that the Upper Irrawaddy at Mandalay and above it was in extreme high flood at this time. The rise there is the very highest ever known. The large embankment erected since the floods of 1868 and 1871 to protect the city was breached and partially destroyed. The rainfall records of Darjeeling, of Sylhet and Chittagong prove that during August the Assam-Thibet branch of the monsoon current was in unusual strength; the latter place having 78 per cent. over its usual monthly supply. All the Aracan and Irrawaddy river stations experienced a deficiency in this month, and there is nothing in the daily record of rainfall at any of these stations to account for the very high rise from the 10th to the 18th of August. A comparison of the form of this last flood wave with that of 20th August 1877 on the diagrams is instructive. The 1875 one is well rounded with a broad base spreading over the greater part of a month. The 1877 one is sharp and with straight edges, and rises on a narrow base from the top of a broader wave. This difference of form proves the former to have come from a source much more distant than the latter. It is evidently the continuation of the great Mandalay flood from the Thibetan regions, perpetuated and sustained by an abundant but not excessive contribution from the Irrawaddy lower tributaries in a moderated form. Had the rainfall of the end of June and beginning

The flood rise at Mandalay in 1875.

Comparison of form of flood waves of 1875 and 1877.

of July been now repeated, with the addition of such a local rainfall near the delta as produced the high rise of 1877, the effects would have far surpassed anything yet experienced. Such a combination of causes is, however, possible, though perhaps improbable. It is nevertheless necessary to remember that such a contingency may arise.

74. A third flood wave of unusual magnitude came down in September. This appears to be due to a heavy rainfall in the Burmese valley supervening on a great discharge of the stored up waters from the Thibetan gathering ground. Sandoway alone exhibits a great excess of rainfall for that month. The southern stations of Burma, Moulmein, &c., show the heaviest excess; a sure proof that the local monsoon centre is far on its southern course. The quantities of water discharged for the four months June to September 1875 are greatly in excess of the average, June by 13,140 million tons or 48 per cent; July 13,468 million or nearly 17 per cent; August by 14,368 or 15 per cent and September by 7,176 millon tons or 9 per cent above the average. For the remainder of the year they fall below the average discharge.

Flood on Nawoon in 1876.

75. In 1876 a local flood occurred on the Nawoon river, the western outlet of the Irrawaddy, which was very destructive to the newly constructed embankment works; but the yearly rainfall over the Irrawaddy basin and the discharge at Myanoung are below the average. The Nawoon flood was due to heavy rainfall over a small area, combined with the influence of the new works. Its consideration therefore belongs to the detailed discussion of the progress and prospects of those works reserved for the last part of this report. It may however be of interest to note the principal features of the 1876 flood rise and rainfall in contrast to those of 1875 and 1877, as its discharge of 381,667 billion tons is almost the smallest on record.

Rainfall in 1876.

76. In April the rain appears deficient over the whole region supplying the Irrawaddy, but the most southern station of Mergui, and the ocean station on the Nicobars were in excess. The Meteorological Report for 1876 records that at the same time there was an unusual abundance of rain over north-west India and the western Himalayas. The Burmese deficiency had thus gone to supply the branches of the monsoon on each side of it. In May this deficiency is more marked for the Aracan and Irrawaddy stations; while the lateral streams are increasing in strength and closing in upon it on both sides. Thus Tavoy, Rangoon and Bassein on the south, as well as Mergui, are largely in excess; and to the north and west Chittagong, Sylhet, and Darjeeling have now a supply above the average; and the monsoon branch bringing this must pass to the Sanpo valley. In June the deficency is again more general; Darjeeling and Prome alone being slightly above the average. The Myanoung gauge diagram shows the ordinary rise of the river to be unusually deferred in June. The calculated discharges give for the dry weather months up to May average amounts of water brought down. The June rise is only explicable on the assumption that the water taken to the Sanpo valley in May had now arrived at Myanoung after traversing from 1,000 to 1,500 miles of channel. The immense deficiency of 21 inches at Akyab, of 16 at Kyouk-phyoo, and 27 at Sandoway being respectively 46, 42 and 51 per cent of the averages for that month on the principal feeding branch of the monsoon to the Burmese basin, with deficiencies also at Sylhet and Chittagong, would inevitably have led to one of the smallest discharges known in June, but for the Thibetan supply. The rise only commenced on the 16th and proceeded rapidly till it reached 27·62 feet on the 2nd July. The discharge for the month was only 4,327 million tons below the average and was much above those of 1870, 1872, and 1874. The July rainfall appears to have been in excess simultaneously over the whole of the areas of the field under consideration, and a discharge of 8,142 tons million

above the average came down in that month. This was followed by a discharge in August of 3,605 millon tons also above the average, although the excess rainfall of July is changed to a large deficiency at every station given, except Sylhet. The river remained nearly at the same level during the month, the diagram showing an unusual flatness of crest on the flood wave, a certain proof that the sources of supply were distant and very much moderated. By far the greater part of this must have come from Thibet. The rainfall for the remainder of the year shows alternations of excess and deficiency, but not ranging far from the average, over all the Burmese stations; but the gauge diagram and the discharges record that an unusual drought prevailed over the principal gathering grounds during the last four months of the year. This peculiarity is especially noticeable in connection with the phenomena of the winter season of the commencement of 1877.

The differences between the monthly rainfalls for 1876 and the averages are given in the following Table :—

Table X.

Name of Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Chittagong...	−0·56	+0·21	−0·21	−3·71	+4·57	−14·94	+10·11	−9·40	−4·27	−4·48	+3·89	−0·37	−9·16
Akyab ...	−0·13	−0·21	−0·45	−1·09	−6·13	−14·25	+7·86	−14·48	+1·68	−6·69	+3·42	−0·17	−27·30
Kyouk-phooo	−0·11	−0·18	−0·43	−1·05	−1·59	−16·94	+10·20	−13·13	−3·58	−3·39	+3·23	−0·12	−26·99
Sandoway ...	−0·07	−0·09	−0·20	−0·78	−8·82	−26·83	+5·97	−25·19	−6·04	−5·07	+2·01	+0·07	−65·18
Thayetmyo...	0·00	−0·04	−0·13	−0·59	−5·80	−0·84	+0·09	−3·51	−2·81	−1·89	+3·47	−0·01	−11·76
Prome ...	0·00	0·00	−0·01	−0·26	−1·81	+2·47	−1·04	−4·09	+2·50	−4·27	+1·42	0·00	−5·09
Henzadah ...	−0·11	0·00	0·00	−0·29	+3·26	−0·45	+2·03	−6·00	−1·11	+0·11	+2·16	0·00	−0·40
Bassein ...	−0·25	0·00	−0·14	+1·15	+1·94	−3·15	+8·88	−4·31	+2·19	+0·25	+0·04	−0·03	+6·57
Rangoon ...	−0·06	−0·06	−0·08	−0·28	+5·26	−7·10	+1·28	−1·98	−0·91	−5·56	+2·79	0·00	−3·70
Tounghoo ...	0·00	0·00	−0·04	+0·64	−3·83	−6·61	+6·71	−5·49	+4·08	−7·25	+1·32	−0·06	−9·55
Shwe-gheen.	−0·01	−0·30	−0·74	−0·26	−3·99	−16·02	−8·00	−6·98	0·00	−8·41	+1·32	0·00	−43·02
Maulmain ...	0·00	−0·04	+0·14	−2·07	−6·67	−2·53	+16·67	−7·71	+5·10	−6·40	+0·75	+0·01	−2·78
Tavoy ...	−0·13	−0·71	−0·58	−0.32	+9·35	−9·81	+17·46	−15·92	−14·45	−3·50	−0·82	−0·12	−19·55
Mergui ...	−0·34	−0·32	−1·77	+6·17	+9·17	−8·27	+15·95	−5·40	+4·65	+1·54	−1·18	+1·59	+21·59
Darjeeling ...	+0·17	−1·09	−0·97	−2·63	+0·34	+3·74	+10·43	−8·47	−4·15	−0·43	−0·13	+0·47	−2·62
Shylhet ...	−0·49	+0·23	+1·89	−8·36	+3·47	−3·26	+3·21	+7·97	−6·16	+0·31	−1·18	−0·15	−1·78

Severe winter of 1876-77.

77. This year presents characteristics of an unusual kind in the extreme contrasts of drought and famine in India and China, and rain and flood in south-eastern Asia. The meteorological report for 1877 has not yet been issued; but Mr Blanford offers some suggestions explanatory of a part of the phenomena in that for 1876. The winter of 1876-77 was one of the severest on record throughout the western Himalayas. He observed the snow to be unusually low and late in the spring of the year in the parts he visited; and Mr. Ryal of the survey mentions that the whole spring continued wet and wintry. The snow lies usually

about 12,000 feet above the sea in April on the hills; this year it was as low as 9,000 feet. In the valleys it was 6,000 feet instead of 10,000 as usual. From other evidence Mr. Blanford believes that this coldness was widely extended. The neighbouring air was cold and areas of high barometric pressure formed. From these northern land winds blew persistently with abnormal strength. Early rain fell in the spring, and was followed by prolonged and intense drought in the summer. He discusses the recent researches on the connection of a maximum of sun spots with variations in rainfall; and is inclined to think that such variations are local rather than general over the earth; and though the exact sequence of causation cannot at present be traced in these and kindred phenomena further researches may show the connections between them. The observations of professor Piazzi Smith may be here mentioned. The earth thermometers buried at Edinburgh and observed since 1837 reveal the regular recurrence of heat waves visiting the earth. One came in 1846·5; one in 1858·0, and one in 1868·7. The next is expected about 1879·5. Cold waves alternate with these, not midway between them, but comparatively closely on either side, at a distance of about one year and a half. He thus expected the winter of 1877-78 to be extremely cold. It did not turn out so generally; but that of 1876-77 was so. That of 1874-75 was also very severe in many countries; and was followed by the flood of 1875 in Burma and famines in India and China. There may be a direct connection between very cold winters and the rain or heat and drought of the following summers; but it is clear that it produces only a transference of conditions from one locality to another, and not a general change in the same direction over the globe.

Deficient discharge of Irrawaddy from September 1876 to July 1877.

78. Whatever the cause of the deficient discharge in the last four months of 1876 may have been, the Myanoung gauge diagrams show that this deficiency persisted steadily through the whole eleven months from September 1876 to July 1877 inclusive. The calculated discharges for this period show the following amounts short of the monthly averages in millions of tons :—

Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.
23,931;	16,020;	5,711;	2,287;	1,806;	979;	1,719;	303;	5,272;	724;	13,676; or
31;	26;	23;	19;	23;	18;	29;	4;	43;	2;	17 per cent.

The fall of rain for the five months January to May for the whole of the Burmese stations is below the average with the exception of Sandoway in the last mentioned month. The generality of this deficiency of moisture on the Burmese side makes it evident that it can only be ascribed to wide-spread and persistent causes; and taken in conjunction with the unusually early and heavy spring rains in the Punjab and northern India in April and May, after the severe winter of 1876-77, the phenomena appear to have a solidarity with those of the whole monsoon region, or at least of the southern part of it. The river reached the lowest limit ever known on the 5th March, when it marked 0·71 feet on the Myanoung gauge The whole of the gauges recorded showed a similiar low state so that it must be taken as the absolutely lowest record known. The calculated discharge on that date was about 45,000 feet per second at Myanoung.

The differences of the rainfall of 1877 from the averages for the stations of Burma are given in the Table below :—

Table of rainfall 1877.

Table XI.

1877.

Name of Station.	January.	February.	March.	April.	May.	June.	July.	August.	September	October.	November	December.	Year.
Chittagong ...	—0·48	+2·58	+0·95	—2·41	—2·92	—4·68	+4·92	+18·90	+8·50	—4·20	—1·42	—0·37	+19·39
Akyab ...	—0·13	—0·21	—0·45	—1·18	—10·71	—7·06	+3·36	+4·58	—2·84	—7·88	+5·13	—0·20	—12·59
Kyouk-phyoo	—0·11	—0·08	—0·43	—1·05	—8·83	—4·36	+17·86	+33·05	+11·18	—0·59	+1·14	—0·12	+57·66
Sandoway ...	—0·07	—0·09	—0·20	—0·78	—12·99	+6·95	+14·14	+24·52	—2·86	—3·84	+6·31	—0·09	+31·00
Thayetmyo...	0·00	—0·04	—0·13	—0·19	—2·83	+4·22	+0·73	+9·89	—4·47	+4·16	+0·18	0·01	+11·51
Prome ...	0·00	0·00	—0·01	+0·43	—3·55	+2·26	—2·22	+2·69	—1·64	+0·13	+5·29	0·00	+3·38
Henzadah ...	—0·11	0·00	0·00	—0·56	—5·38	+3·52	—1·37	+4·70	—1·42	+2·38	—0·30	—0·00	+1·46
Bassein ...	—0·25	0·00	—0·14	—1·02	—1·22	+17·63	+5·65	+12·16	—6·05	—0·71	—0·45	—0·03	+25·57
Rangoon ...	—0·06	—0·06	—0·08	—1·69	—11·17	+7·28	+0·67	+2·80	—1·74	+2·27	+1·51	0·00	—0·27
Tounghoo ...	0·00	0·00	—0·04	—0·96	—6·13	+6·39	+5·94	—2·13	—1·76	—0·44	+2·54	—0·06	+3·27
Shwe-gheen.	—0·01	—0·42	—0·66	—1·61	—13·38	+2·72	+7·89	+0·25	+4·53	—2·32	+1·72	0·00	—3·36
Maulmain ...	0·00	—0·04	+0·31	—3·09	—9·80	+1·79	—9·09	+3·75	—11·21	—1·37	—0·94	—0·01	—26·65
Tavoy ...	—0·13	—0·71	—0·53	—2·27	—0·40	+15·29	+9·41	+13·38	—21·44	—3·26	+0·28	+0·92	+11·34
Mergui ...	—0·41	—1·27	+1·74	—4·34	—1·24	+1·04	+1·32	+1·24	—8·83	—3·34	—0·56	—0·44	—15·09
Darjeeling ...	+1·79	+0·24	+1·03	+3·13	+1·23	—11·06	+5·54	—11·86	+1·94	—5·84	—0·17	+0·42	—13·61
Sylhet ...	+2·36	+0·38	—2·30	—11·09	—2·95	—2·87	+3·84	—6·08	+28·04	—5·80	+0·53	+0·52	+4·58

Physiological effects of the prolonged drought of 1876-77.

79. The prolonged drought was intensified in the hot season of March, April and May in Burma, and was accompanied by an unusually unhealthy condition of the atmosphere and other environments, felt over the whole of Burma from Bhamo and Akyab to the southern limits, the effects of which remained for some considerable time. It seemed as if the power of sustaining life were taken out of the air ; and there was a general lowering of the vital energy. The most healthy felt intense depression and langour, with lessened capacity to think or to act. The weakly and the young and aged suffered more severely. A sudden outburst of disease developed all over the country ; malarious fevers, typhoid, typhus and brain fever with dysentery, smallpox and cholera seemed to come simultaneously into existence in localities where some of them were before unknown in epidemic form. In the larger towns this was more conspicuous, hardly any escaping ; but there is reason to know that disease was widely spread over the more remote parts, though statistics are wanting. As a rule Burma is a very healthy country, notwithstanding its extremes of heat and moisture. Pemberton (1) has collated the testimony of several of the older authorities on this point, and while exceptional experiences such as of armies in the field, or badly housed in unfavorable conditions, where they have suffered severely, have been unfavorable, the general conclusions as to the salubrity of the country are unanimous. And

(1.) Pemberton Captain. Report on the north eastern boundaries of India.

the universal testimony since is to the same effect. That the evil was due solely to the prolonged drought extending over eleven months, and not to the lateness of the monsoon of 1877, is made evident by the experience of the present year (1878) when the whole monsoon season was extremely backward without injurious consequences to health.

The heavy rainfall of the monsoon months.

80. The details of the rainfall at Indian stations are not at present available, but from the Burmese records it is manifest that the drought of spring was replaced in June by a general excess of rain at all the stations except the two most northern ones of Akyab and Kyouk-phyoo. The shape of the flood wave on the Myanoung diagram would indicate very heavy showers of rain in the neck of the valley above the delta, throwing a sudden discharge on top of a moderated low flood wave coming from distant sources. The short supply passing over the two northern Aracan stations manifests a deficieny in the main body of the Irrawaddy basin and lower tributaries in June. In July and August the Aracan group of stations have large excesses, Akyab 6·81 inches and 4·60 inches respectively; Kyouk-phyoo 15·41 and 29·46; and Sandoway 14·15 and 24·52 inches above the usual monthly averages. The stations of Thyetmyo and Prome representing the neck of the Irrawaddy basin above the delta have about the average supply in July; but Thyetmyo is largely in excess by 7·89 inches or 70 per cent. in August. The southern stations appear above the average for those two months.

Notice of the general characteristics of the monsoons of 1877.

81. Before considering these rainfalls in closer detail it will be well in the absence of specific information regarding the meteorology of the regions outside the Burmese field, to resume in a brief manner what is known generally regarding it for this portion of the 1877 season. The early rains of northern India at the time of the drought of March to May in Burma, were succeeded by a loss of the ordinary supply over the whole of the western portion of the Peninsula during the mid-summer months, while the eastern side of it in Lower Bengal and Assam, with the Bay of Bengal and the Burmese peninsula received a more abundant supply than usual. It seemed as if a total reversal of the previous state of things had been brought about, and as if a complete transference of the rain bearing winds of the monsoon had occurred from the south-western to the south-eastern quadrant of the outer monsoon region. In July the writer had an opportunity of personally witnessing the different phases of the phenomena. He crossed the Bay of Bengal from Rangoon to Calcutta, and went as far as Simla in the Punjab. Here and in the North-West Provinces famine was already threatening from the want of the usual rain. In Burma at this time the monsoon had set in with unusual violence. In the Bay of Bengal steady winds alternating with storms from the S.W, but with no signs of cyclonic movement, predominated. The precipitation of rain over the whole surface of the Bay was great and abnormal. This state continued through August, when the writer returned. The logs of the steamers crossing the Bay about this period prove that the exceptional atmospheric disturbance was general and persistent. Statements in newspapers and official reports indicate that excessive humidity followed by floods prevailed over the greater part of south eastern Asia; while the drought spread over India and China, acquiring a definite and permanent form, and entailing famine and devastating disease.

The July rise of the river,

82. The branch of the monsoon passing over eastern Bengal and Assam reached Thibet, and must have carried a deficient supply of rain to the valley of the Sanpo and to neighbouring regions in May and June, from the form of the flood wave at Myanoung in July, when its flattened top from the 26th June to 23rd July, on each of which dates it was at about 25 feet on the gauge, proves the mass of the water to have been from highly moderated soures, probably from the lower

tributary valleys, with a small supply from Thibet. The smaller waves riding on top of this are clearly from heavy showers in the neck of the basin, but the rounded forms of the two which culminated on the 8th and on the 15th July show that these also were somewhat moderated ; and probably came from the higher part of the neck or lowest part of the Burmese basin of the river. The next wave, which lasted from the 23rd July to the 11th September, is the most important on record from the extreme height of its crest both above all others, and above what may be called the trough of the wave. It needs to be studied in close detail.

Table XII.

83. *Daily Rainfall for July* 1877.

Date.	Akyab.	Kyouk-phyoo.	Sandoway.	Theyetmyo.	Prome.	Myanoung.	Henzadah.	Bassein.	Total
1	0·00	0·20	5·40	0·80	0·24	0·00	0·25	0·13	56·65
2	0·12	1·20	2·13	0·12	0·30	0·40	0·14	0·98	63·50
3	3·76	2·50	3·08	0·34	0·80	0·90	0·26	0·48	74·93
4	2·30	3·20	8·22	0·78	0·08	1·40	0·32	1·91	9·91
5	2·73	3·20	1·03	0·54	0·79	0·20	0·13	0·89	7·15
6	2·77	2·00	2·58	0·10	0·14	0·40	0·87	0·02	8·70
7	0·17	2·00	6·22	0·00	0·60	0·10	0·81	0·95	18·02
8	3·56	4·50	5·15	0·00	0·60	0·00	0·68	1·20	31·93
9	0·15	0·50	·241	0·00	0·00	0·00	0·70	2·54	
10	1·52	7·00	5·81	0·22	0·00	0·40	1·56	2·54	
11	2·38	6·70	4·39	0·26	0·15	0·30	1·38	2·28	
12	4·15	0·70	1·50	1·32	0·23	0·60	0·63	0·065	
13	0·67	2·30	0·23	0·84	0·08	0·06	0·40	0·11	
14	2·93	0·10	0·20	0·32	0·53	0·10	0·28	0·13	
15	0·24	2·70	0·71	0·00	0·05	0·10	0·00	0·56	
16	2·41	0·20	0·97	0·62	0·02	0·00	0·11	1·21	
17	0·06	0·70	1·85	0·20	0·29	0·40	0·10	0·62	
18	2·54	1·00	1·95	0·04	0·00	0·10	0·45	3·90	
19	1·73	0·80	0·15	0·09	0·00	0·10	0·71	3·21	
20	1·43	1·50	0·11	0·28	0·00	0·00	0·09	0·12	
21	2·81	2·50	0·43	0·80	0·96	0·00	0·04	0·07	
22	4·36	5·00	3·25	1·63	0·78	0·70	0·00	0·24	
23	0·10	1·00	3·41	0·42	0·15	0·30	0·91	1·73	
24	1·34	1·00	0·50	0·12	0·19	0·30	0·93	2·19	
25	0·50	1·00	0·08	0·00	0·12	0·00	0·25	0·68	
26	0·15	0·80	1·29	0·00	0·00	0·90	1·74	0·91	
27	1·33	2·80	1·12	6·00	0·19	0·10	0·41	1·38	
28	2·88	1·00	4·19	0·00	0·00	0·20	0·54	0·09	
29	3·69	1·20	4·76	0·24	0·05	1·40	0·13	0·10	
30	1·74	3·00	1·15	0·44	0·21	0·30	2·40	0·24	
31	1·53	1·20	0·60	0·34	0·20	0·00	0·80	0·46	

Daily Rainfall for August 1877.

Date.	Akyab.	Kyou-phoo.	Sandoway.	Theyetmyo.	Prome.	Myanoung.	Henzadah.	Bassein.	Total
1	0·00	3·00	6·25	0·05	0·07	0·40	0·33	0·93	40·99
2	0·69	1·90	3·15	0·14	0·21	0·70	0·54	1·195	72·70
3	1·25	6·00	2·92	0·10	0·17	0·90	1·12	2·315	74·13
4	1·23	7·00	8·80	0·40	0·65	0·50	1·39	1·67	22·13
5	1·36	4·00	11·34	0·42	0·21	1·80	0·29	3·10	17·15
6	2·33	12·00	3·07	3·48	0·78	1·00	2·98	0·52	13·80
7	6·28	2·00	2·53	1·60	3·28	0·10	0·59	0·66	21·12
8	2·13	2·70	2·70	3·60	0·63	0·30	0·75	0·08	
9	0·98	1·00	0·60	0·04	0·77	0·10	0·67	0·01	
10	0·25	1·00	3·71	0·00	0·00	0·10	0·17	1·30	
11	0·51	0·50	2·82	0·00	0·00	0·00	0·00	1·03	
12	1·11	2·00	1·45	0·10	0·35	0·40	1·08	5·91	
13	1·22	3·00	2·04	0·54	0·00	0·70	0·40	2·51	
14	2·18	2·00	0·49	0·00	0·43	0·00	0·38	0·82	
15	0·24	0·30	0·42	0·48	0·40	0·00	0·28	0·26	
16	0·32	2·00	1·05	0·18	0·08	0·10	0·14	0·35	
17	1·47	5·00	3·07	0·80	0·00	0·80	0·96	0·04	
18	0·58	4·00	1·53	2·84	1·64	2·40	1·16	1·06	
19	5·00	5·00	3·75	0·02	4·03	0·50	4·28	0·575	
20	3·90	1·00	0·93	0·00	0·54	0·10	0·00	0·655	
21	0·04	2·00	0·87	0·76	0·00	0·10	0·00	2·645	
22	0·51	2·00	4·03	0·32	0·07	0·10	1·40	0·095	
23	3·44	1·00	0·36	0·00	0·00	0·00	0·00	0·00	
24	0·00	0·40	0·10	0· 0	0·07	0·00	0·00	0·00	
25	0·00	0·20	1·94	1·78	0·00	0·10	0·00	0·03	
26	0·27	0·10	0·21	0·36	0·13	0·20	0·95	0·29	
27	0·11	0·10	1·03	2·02	0·61	0·50	0·19	4·76	
28	0·54	0·00	0·34	0·24	1·14	0·70	0·84	0·26	
29	1·33	1·50	2·21	0·10	0·21	1·10	0·06	0·33	
30	1·62	0·00	0·00	0·76	0·64	0·00	0·17	0·34	
31	0·10	0·00	0·42	0·00	0·04	0·10	0·00	0·23	

The great flood wave of Aug. 1877.

84. The great flood wave of August 1877 as presented on the Myanoung gauge diagram offers peculiar features. It rose with almost perfect uniformity from the gauge reading of 24·98 on 23rd July to the reading of 40·31 feet on 10th August, or at the rate of 0·8 feet per day. On the 12th it marked 40·35 feet on the gauge, which had been adjusted in common with all the Irrawaddy gauges to read 40 feet at the highest flood mark of 1875. The diagram shows the rise as almost a straight

line. The crest is gently rounded, and the fall proceeds slowly, as though to reach a small trough on the 24th; when, on the 19th and the 20th, there is a sudden sharp rise, with a quicker subsequent fall. This second acute wave riding as it were on the back of the other is the very highest rise ever known in the delta of the Irrawaddy, and in that part of the neck of the basin lying between Myanoung and Thayetmyo. It stood at Myanoung 0·96 feet above the highest rise of 1875, and 0·61 feet above that of 12th August 1877. Before examining the origin of this the generation of the principal wave must be considered.

Origin of the 1877 flood wave

85. The central monsoon stream passing to the main indraught area of the Thibetan plateau, from the Bay of Bengal must have shared in the excess of moisture evidenced by that shed over Bengal and Assam in July and August; and the Thibetan feeders of the Irrawaddy would be in extreme flood during July. This flood discharge could only reach Mandalay late in July or in August. We have the data furnished by Mr. Bain, which fixes exactly the relative height of the river at the capital of Upper Burma. The flood rises from 1872 to 1877 are, as before given, above the low water of 1873.

1872	1873	1874	1875	1876	1877
20·5 feet	19·33 feet	22·5 feet	26·25 feet	24·75 feet	25·66 feet

The 1877 rise at Mandalay is thus 0·59 feet or 7 inches lower than that of 1875 showing a considerably smaller contribution from Thibet than in the earlier year. It is nevertheless, with that one exception, the highest rise upon record at Mandalay. The immense width of the river there, and the broad plain the flood water can spread over when the banks are inundated, makes a few inches rise signify a great difference in the quantity of water discharged. As the river in the lower parts rose higher in 1877 than in 1875, we must seek an explanation of this difference in the rainfalls of the lower stations.

Great daily rainfalls July.

86. The table with the daily rainfalls for July and August at the Aracan and Irrawaddy stations for July and August 1877, offers some noticeable features. In examining the small rises on the flat top of the July flood wave it was stated that the form of these led to infer that they had their origin in the lower part of the Burmese basin and in the neck of the valley. Sandoway lies right in the track of the monsoon branch supplying this region with rain. Here 5·4 inches fell on the 1st; 3 inches on the 3rd; 8·22 inches on the 4th; and 6·22 and 5·15 on the 5th and 6th July. These were supplemented by smaller showers. Thayetmyo has falls of 0·80, 0·34 and 0·78 inches on the 1st, 3rd and 4th; Prome of 0·80 and 0·79 on the 3rd and 5th July; which indicate the nature of the falls over this area and account for the first of these small waves.

Comparison of rainfall with state of river.

87. The rainfall for July was 13 per cent above the average at Akyab, 32 per cent at Kyouk-phyoo, and 24 per cent at Sandoway; and for August it was 12, 70, and 49 per cent respectively. If, as there is every reason to believe, the average rainfall over the main body of the Irrawaddy valley and lower tributaries would just suffice to perpetuate and preserve the characteristics of the flood wave arriving at Mandalay from the north, it is evident that such an excess as those figures indicate spread over the whole basin would intensify the great flood wave, known to have reached Mandalay early in August, in all the lower parts of the channel. It is a pity the data to reason upon are so few. We are delivered to conjecture on the most important points. Nothing but a reliance on the regularity of the phenomena can justify any analysis whatever of the floods from the records we possess; but so far as they go, and proceeding on the assumption that the records of the sea coast stations do give some indication of

the rate of supply from the monsoon streams passing over them to the Burmese valley, we can in a measure follow the variations of the flood waves. We know that the great wave of 1877 commenced to rise at Myanoung on the 23rd July. We also know that its crest reached Mandalay early in August, and that it was at Thayetmyo on the 11th, at Prome on the 10th, and at Myanoung on the 12th. At what dates did it commence to rise at Prome, at Thayetmyo, at Mandalay, and at Bhamo? No information is forthcoming on these points. As there is an engineering staff at the two former places, systematic gauge records could be kept there with great facility. As it is, it is only by a series of chances that exact figures could be obtained about the height and the dates of the flood there.

Heavy daily rainfalls in beginning of August.

88. An inspection of the daily record of rainfall shows that a great though not excessive rainfall occurred from the 21st to the 23rd July all along the line of the Aracan and Irrawaddy stations, which would meet the flood wave coming from the north about that time. Somewhat heavy falls were recorded at intervals from then to the end of the month, followed by enormously heavy ones at the southern Aracan stations, as well as at the Irrawaddy ones. Thus we have 6, 4, 7 and 12 inches on the 3rd, 4th, 5th, and 6th of August at Kyoukphyoo; 6, 9 and 11 inches on the 1st, 4th, and 5th at Sandoway; and the abnormally heavy falls for Thayetmyo and Prome of 3·48 and 3·60 inches at the former on the 6th and 8th, and 3·28 at the latter on the 7th. The discharge from the hill streams consequent on those showers must have just met the front of the wave in the confined channel from Maloon to Myanoung.

Progress and height of the great flood wave in Lower Burma.

89. Lieutenant Lloyd, R. E., officiating Executive Engineer at Thyetmyo, states that the height of the wave there was 2·2 feet on the 11th August above the highest of 1875 at that place. Mr. Henderson, late Executive Engineer of Prome, states that this first rise was 1·79 feet above the 1875 flood mark there on the 10th August. Plate V. permits its subsequent course down the river Irrawaddy to be traced. At Saiktha it stood 1·08 feet above the flood of 1875 on the 11th. At Myanoung it marked 40·15 feet on the 12th. It is to be remembered that 40 feet denotes the highest rise of 1875 for all these gauges. At Shoaygheen it marked its highest of 40·41 on the 12th and 13th; this place being 21 miles lower down the river than Myanoung. It reached Henzadah on the 15th, 68 miles from Myanoung, and marked 40·15, its excess thus diminishing greatly. By the time the crest reached Donabyo some 46 miles lower down it was actually lower than the high mark of 1875, by 0·17 feet. There will be need to recur to this peculiarity in considering the moderating effect of the river channel in the delta. At present it will suffice to note that the diminution of height of the 1877 wave relative to that of 1875 appears due to the greater mass of the July wave in the earlier year, which filled the channel and low lands of the delta before the advent of the great rise of August.

The second and highest rise in August 1877.

90. The highest rise of the year culminated at Myanoung on the 21st August. The crest of the great flood wave had passed down the river; the surface was slowly falling and marked 39·33 on the gauge on the 18th, or one foot below its height on the 12th, when a sudden rise of 1·19 feet on the afternoon and night of the 18th, and another of 0·44 feet on the 19th brought it up to 40·96 feet on the gauge on the morning of the 20th; nearly one foot above the highest rise of 1875. The fall was still more rapid. On the morning of the 22nd the gauge read 37·92 or 3·04 feet below the highest point. Further up the river the rise and fall were still more remarkable. At Saiktha, 16 miles above Myanoung, the river rose from 39·75 feet on the morning of the 18th, to its highest at 41·88 on the gauge on the 19th, or 2·13 feet in 24 hours; being 1·88 feet above the highest mark of 1875. It fell to 39·50 in two days, and the acute rise was absorbed in the greater wave. At Prome, over 50 miles north of Myanoung, Mr. Hen-

derson records that the river was falling after the flood of the 10th, when it commenced suddenly to rise on the 18th, and attained the level of the previous rise on the evening of the 19th, or 1′ 9½″ above the flood of 1875. The river did not rise so high at Thayetmyo on this second occasion as on the first, and the absence of a river gauge and records at this place prevents any information being obtainable about it. But from this part to Mandalay the second rise was unimportant compared to the first; and there is evidence that it was purely a local rise confined to the neck of the valley and to the delta of the river. It appears to have been most intense between Prome and Saiktha, where the rise was most acutely felt. In the delta the moderating effects of the channel were made visible, and are shown in Plate V.

Progress of second rise in river channel in delta.

91. Sixteen miles south of Myanoung the river rose 1·25 feet, and 36 miles off, 0·75 feet in two days. At Henzadah the rise was 0·55 feet spread over three days, at Zaloon 0·41 and at Donabyo 0·21 feet. The river to the south of Myanoung receives no rain supply but such as falls on the surface of the channel; and though from Myanoung to Donabyo the distance is nearly 120 miles, with over 300 square miles of surface, the quantity received is inappreciable compared with the great mass of water carried by the river. Plate VI represents the height of the different floods on the Nawoon branch of the Irrawaddy, but as the effects of the embankments intervene and complicate the question here, the discussion of this is reserved for the last part of this report, when the works and the floods on the Nawoon will be considered in detail.

The second rise due to heavy rainfall in hilly regions of neck of valley.

92. The origin of this remarkable flood rise can only be understood after a careful consideration of the arrangement of the influent streams entering the Irrawaddy between Thayetmyo and Prome. Almost all of these on both banks retain the north and south directions of the tributaries generally. The Moo river on the west bank extends far into Upper Burma, and though its course has not been surveyed accurately, it is believed to reach to the north of Maloon, and to drain most of the hilly country on that side of the neck of the valley. Two large streams, the Booday and the Nawing, enter on the left side. The former extends far beyond the British frontier and the two together drain a very large portion of the hilly region on the east bank. The rainfall precipitated over the greater part of this country thus finds its way to the Irrawaddy between Thayetmyo and Prome. The daily records of the stations show that extremely heavy showers fell over all the lower part of the Irrawaddy valley between the 17th and 19th August. Five inches are marked at Kyouk-phyoo on the 17th, the average daily fall being 1·37 inches; and Sandoway had 3·07 inches against a normal one of 1·54 inches. The falls at the Irrawaddy stations were above the average. On the 18th Kyouk-phyoo received 4 inches; Thayetmyo 2·84 instead of 0·33 inches; Prome 1·64 instead of 0·47; and Myanoung 2·4 in place of the usual light supply. The last three falls indicate an excessive and abnormal precipitation, especially over the right bank of the river in the hilly region of the neck, and there can be little doubt that to these intense local showers, which were a part of a general and wide-spread rainfall, the acute rise of the river on the night of the 18th August was due. The rainfall appears to have been still heavier on the 19th at all stations except Thayetmyo and Myanoung, which are on the right bank. Prome on the left bank received the—for that place—enormous fall of 4·03 inches instead of 0·47. It would seem that there was a local transference of the showers from one side of the river to the other. Henzadah in the delta received 4·28 instead of 0·52 inches. The heavy falls on this date at the Aracan stations were most likely prolonged northwards, but we have no details on this point. The whole of this hilly region would be nearly saturated beforehand by the previous falls of rain, and the steep declivity of the torrent beds, and the absence of all moderating influences such as intermediate permeable strata or large channels would permit the great body of the water to be

thrown simultaneously into the channel over 100 miles of its confined and rock-bound course.

The flood wave of September and October 1877.

93. The succeeding flood wave which lasted from 12th September to 26th October is hardly less remarkable from its abnormal departure from the usual condition of the river at that season. It exceeded in height and in mass the principal flood waves of ordinary years. As shown in the Myanoung gauge diagram, it had there a comparatively rounded form with no sharp rise in any part of it. This indicates somewhat distant and highly moderated sources of supply for the greater part of its mass. The records of September and October show a rainfall either about or below the average for most of the stations; Kyoukphyoo alone having the large excess of 11 inches in September. A sharp rise and fall about the 26th October could only be due to heavy showers in the neck of the valley. It is probable that the great body of the wave was made up of a late supply from Thibet joined by the excessive though moderated discharge of the great August rainfall from the reservoirs of the Kyendwin and other tributaries and basin of the Upper Irrawaddy. The river thus becomes an indicator of the condition of the otherwise unknown region to the far north.

Comparison of the discharges in the great flood years.

94. The average discharges for each month of the year and for the whole year are given in the following table, with the differences between these averages and the monthly discharges of the great flood years 1871, 1875, and 1877. The figures represent millions of metre-tons.

Table XIII.

Average discharges of the Irrawaddy at Myanoung.

January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
7,785	5,443	5,886	8,359	12,413	32,214	80,559	95,150	77,073	62,061	25,256	12,564	424,763
Differences between above and discharges of the year.												
1871.												
+147	—194	+882	+980	—857	+12,322	+8,418	+7,024	+17,379	—3,696	+11,445	+3,024	+56,876
1875.												
+34	+95	+202	+2,625	+9,238	+13,140	+13,468	+14,357	+7,176	—12,123	—5,518	—1,989	+40,067
1877.												
—1,806	—979	—1,719	—303	—5,272	—724	—13,676	+27,455	+9,442	+22,274	+5,044	+1,624	+41,357

Plate IV represents graphically the whole series of discharges from 1870 to 1877, and permits the peculiar features of the floods to be readily apprehended. The greatest monthly discharge was in August 1877, when 122,604 million tons were carried past Myanoung. This mass far surpassed those of the same month in 1871 and 1875 when 102 and 109 billions were discharged, but the great deficiencies of the early months of 1877 permitted the total for the year 1871 to surpass that of the former years. A comparison of the average discharges of the first six months of 1871 and 1875 with those of 1877 makes it clear that no prognostics of the summer monsoon discharge can be deduced from that of the spring months, as there is an entire reversal of the relation between the first two and the third. The deficiency of nearly 14 billions in July 1877 immediately before the great excess of 27 billions in August is particularly notice-

able after the excesses of June and July 1871 and 1875, which seemed to herald the approach of the great floods of those years in August. The greatest daily discharge in 1871 was 4,092 million tons on 6th and 7th August. That of 1875 was 4,608 million on the 17th August; and the first great rise at Myanoung on the 12th August gave 4,748 million tons on that day The second high rise reached the enormous quantity of 4,991 millions on the 20th. The actual quantity which served to give the peculiar features to this rise, and which was thrown into the river between Thayetmyo and Myanoung in 3 or 4 days on top of the high flood then passing may be approximately estimated by drawing on the discharge diagram a line from where the flood line intersects the ordinate of 18th August to that of the 22nd August. The portion cut off represents the quantity forming the second rise. On the 18th the quantity passing down with the main flood would have been 4,075 millions; it took 740 millions additional to raise the river about two feet. The quantity added on the 19th was 1,026 millions, and on the 20th 373 millions, the total precipitation of water into the channel of the river being thus 2,139 million metre-tons in three days from some 12,000 to 15,000 square miles of hilly land in the neck of the valley.

A greater flood than yet experienced is possible by a re-arrangement of the conditions of the 1871, 1875 and 1877 floods.

95. A careful examination of the conditions attending the formation of the fore-described floods proves that such an arrangement of the several elements contributing to their production as would adjust their extreme effects in combination together on the passage of a wave down the river would entail a high rise and destructive results far exceeding anything yet described. In 1875 there was an excessive flood from the far north arriving at Mandalay. It met on its passage from Mandalay to Maloon only the moderated discharge of the July rainfall in the basin and lower tributaries of the Irrawaddy. Had the August rainfall of 1877 recurred immediately after the July rainfall of 1875, the flood of that year would have arrived in British territory with a much more acute rise than either of those years floods. And had the 2,000 million tons of water mentioned in the last paragraph been thrown in on top of the crest of a great flood wave, such as that now contemplated, there can be no doubt that the rise would have far transcended those of the great floods experienced of late years. It is highly improbable that such combinations should occur. It is, nevertheless, necessary to note that a very slight re-arragement of the conditions actually known to have occured may produce consequences unpleasant to consider and which it is not reasonable to expect any embankment constructed can be prepared to resist.

96. We have now to pass from the consideration of the floods as generated and fashioned by nature under the hydrological conditions stated to that of the same floods both as formative agents, and as themselves liable to modifications in their passage through the delta channel in their form and in their effects. So far as this modification is subjected to human control it constitutes the practical hydraulics of the delta of the Irrawaddy. Part III of this report is devoted to a general discussion of some of the hydraulic problems presented.

APPENDICES TO PARTS I & II.

APPENDIX I.

GEOGRAPHY OF THE IRRAWADDY VALLEY AND NEIGHBOURING REGIONS.

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APPENDIX II.

PIECES JUSTIFICATIVES.

THE IRRAWADDY AND ITS TRIBUTARIES.

IRRAWADDY—MAIN CHANNEL—BETWEEN SALE AND WET-MA-SUT.

"At five in the evening we reached Sillah Mew (Salé) on the east bank of the river. From "Wet-ma-sut up to this place after which it narrows, the Irra-
Crawford J. Journal of Embassy to Ava . p. 103 and 136. "waddy has a great breadth. In some situations to all appear-
"ances, it was not less than four miles across." * * *

p. 136 Sept. 28th. "After passing Samai-Kmo we came to the termination of the largest island "which we had met in the Irrawaddy and which extends all the way from the confluence of the "two rivers to the place we were now at: it is called Ala-Kyun or middle island, it is high and "generally cultivated. After this the Irrawaddy expands to a breadth which was at present not less "than four miles: it is full of low islands, evidently inundated during the highest rise of the water."

TRIBUTARIES OF IRRAWADDY.

"From the town of Ava to its debouchement, the Irrawaddy receives no tributary stream of the "least importance, except the Kyen-dwin, and does not throw off
Do. Vol. II, p. 228. "a single branch."

KYEN-DWIN.

"The Kyen-dwin river, much inferior in size to the Irrawaddy, appears to have its origin in the "mountains of Assam. It falls into the Irrawaddy in the latitude
Do. p. 229. "20° 35', after running over five degrees of latitude in a course nearly south."

MYIT-NGE.

"The Myit-ngé on the east face (of Ava) forms a considerable part of the defence on that side. This "river about one hundred and fifty yards broad, is a fine rapid
Do. Vol. II. p. 3, 4. "stream, and the banks of it very steep and high: the rivers not "running in such a manner as to form any part of the defence of the south-east angle of the city, a deep "canal has been cut from the Myit-ngé, at the south-east angle, to about one-third the way down the "east face of the city wall, where it falls into the same river. The torrent here is very rapid—so much "so—that boats can with difficulty stem the stream."

IRRAWADDY AT MANDALAY.

July 17th 1795. "The river, which though it had not yet risen to its utmost periodical height, "had overflowed its banks, filled all the water courses, and inun-
Symes Lieut.-Col. Michael. Account of an Embassy to the Kingdom of Ava p.p. 9 10,68, July 17, 1795. "dated the low grounds adjacent to its bed. As the force of the "current lay in the middle of the stream in order to avoid "its influence we frequently navigated through fields; in which the tall grass and reeds appeared "above the surface of the water, and the trees had their stems immersed beneath the flood. The "swelling of the Irrawaddy is not influenced by the quantity of rain which falls in the valleys, but by "the torrents that rush down from the mountains. Notwithstanding the drought in the champaign "country had been greater this year than usual, the river was swollen to its regular height, which I "I was informed, it rarely fell short of or exceeded. Indeed, this part of the country is seldom re-"freshed by copious rains, but, like Egypt, depends on the overflowing of its river to fertilize the soil. "The Irrawaddy during the monsoon months rises and subsides three or four times." * * *

p. 86. "The river which had now risen to its utmost height, had encroached so much on the grove, "as to threaten a general inundation; and we began to think it not improbable that we should be "obliged some night hastily to change our residence from the house to the boats. The cause of "the swelling of the waters was not apparent, as there had not fallen with us a sufficient quantity of "rain to produce the smallest alteration in the body of the river."

IRRAWADDY AT BHAMO.

p. 174. "At Bhamo the Irrawaddy is divided into three channels; the western and centre chan-
"nels not visible, that on the east or left bank about 200 yards
Bayfield Dr. G. T. Narrative of journey from Ava to the frontier of Assam and back —between Dec. 1836 & May 1837, p.p. 174, 95 "wide. The Myo-woon came up the left channel and arrived an "hour and a half before me."

TRIBUTARIES OF IRRAWADDY-SHUELI.

"To this point of their progress no diminution in the volume of the Irrawaddy was percipti-
"ble, and the channals proved sufficiently deep for the passage of
Hannay Capt. S. F. Abstract of a route travelled by Capt. Hannay.
"of large boats, from which we may infer that all the principal
"feeders or affluents which pour their tributary streams into the
"Irrawaddy were still further north and had not yet been reached. The first of any importance noticed
"is the Shueli-kyoung on the left bank, the northern-branch of which flows from the Chinese frontier
"town of Santafu, called by the Burmas Mola Santa, and a southern branch from Momeit, the site
"of the celebrated ruby mines already noticed. The confluence of these streams is represented as
"occurring at the village of Laha, about 40 miles from the Irrawaddy. Neither branch can be of
"any magnitude, for Capt. Hannay remarks that at the point of junction with the Irrawaddy the
"breadth of the Shueli is not more than 300 yards, and that it contained but little water—a satis-
"factory proof that this stream can have no connection with the Tsanpo of Thibet."

TAPING RIVER.

"Capt. Hannay describes the Taping as not more than 150 yards broad and with only sufficient
Do. p. 93.
"water to float a small boat."

MOGOUNG RIVER.

"On the last day of December the mission reached the mouth of the Mogoung river, which
Do. p. 96.
"Capt. Hannay ascertained by observation to be in latitude
"24° 56' 53". Here they were to quit the Irrawaddy which
"says Capt. Hannay is still a fine river flowing in a reach from the eastward half a mile broad, at the
"rate of two miles an hour, and with a depth varying from three fathoms in the centre to two at
"the edge. The Mogoung river, on which the town of the same name is situated, is not more
"than a hundred yards wide."

SHUELI RIVER.

"Reached the mouth of the Shueli river in the afternoon and rowed up several miles to the
Williams Dr. Through Burma to China, p. 171.
"village of Negwen in the small boat. As far as we went the
"river was about two hundred yards wide and a little wider near
"the village, but encumbered with shoals and sandbanks. The
"water was ten or twelve feet from the top of the banks. Both banks are under water during the
"floods."

BHAMO DEFILE.

February 15th 1863. "At one of the narrowest parts I found the breadth of the river to be
Do. Through Burma to China, p, 22.
"not less than 970 feet though, judging by the eye, I could not
"believe it to be more than 150 yards." * * * "As to the
"depth close to the face of the cliffs, the ten fathoms line could not reach ground; but at another spot
"I found bottom near the centre at eight fathoms."

IRRAWADDY—TSHENBO DEFILE.

"The Irrawaddy at the beginning of the first defile about five miles above Bhamo, is about 1,000
Anderson J. Dr. The Irrawaddy and its sources, p. p. 5, 7, 8.
"yards across and its course is defined by low wooded hills which
"run close to its banks. There the river has cut a passage for
"itself through the solid banks in some places not more than 50
"or 60 yards broad but 10 to 12 fathoms in depth. The current is not so strong in the dry
"weather as to interfere materially with the passage of boats when they are kept under the lee
"of the greenstone beds; but we had telling evidences in the height of the high water mark, which
"was about 25 feet above the level of the river in February, and in the shivered trunks and
"branches of large trees heaped in wild confusion among the rocks, that all navigation must be
"impracticable during the height of a flood, and that the body of water which pours through this
"narrow gorge must be of enormous, and of terrific power."

"There is a small isolated rock, on the right side of the channel, capped by a Pagoda and
"another little promontory further on with a similar structure. The first appears to be of great
"age, and its presence on the rocky island—well into the middle of stream, and not higher, I
"should think, than 45 feet above it—gives us some indication as to the limit of the rise of the
"river, for the pagoda could not withstand the power of the current. It must be borne in mind
"however that the Irrawaddy had not reached its lowest (point) when I visited this spot."

MOGOUNG RIVER.

April 10th 1837. "Mogame is a rather pretty town, situated on the right bank of the Mogoung "river at the confluence a river 100 yards broad the water of which "spreads out in some places, to a considerable breadth and depth. "The country is however low, flooded in the rains." * * *

Griffith, Dr. W. Journals of travels through Assam, Burma, etc., p.p. 91,2,4,5.

p. 92, April 23rd 1837. "Arrived at the Irrawaddy. The Mogoung river is very uninteresting "the stream being generally slow, sandbanks very abundant, as well as stumps of sunken trees. At "its month it is deep, and about seventy yards across." * * * p. 93. "The Irrawaddy op- "posite the entrance of the Mogoung river, is 600 yards across. It is a noble stream; has risen "a good deal, and presents one unbroken street of water. The banks are by no means high and are "grassed to the brink. The water is cold and clouded; its temperature is 66½° that of air in a "boat 88½°."

IRRAWADDY—DEFILE ABOVE BHAMO.

"The Kkyouk-dweng is a remarkable and awful object. The greatest breadth of the river while "confined within this defile does not exceed 250 yards and in all "the bad places it is contracted to within 100 occasionally 50."

Do. p. 94.

* * * "The depth is of course enormous, in the low state of the river, when Bayfield passed "up, in many places no bottom was found at 25 or even 40 fathoms, and at this season the "water had no doubt risen 40 feet higher. Some idea of the rise that has taken place may be form- "ed from the fact, that in places where, when Bayfield passed up, the stream did not exceed 70 yards "in width, it was now 200; and of course a rise of 20 feet in the open river, would determine one of "at least 40 within the Kyouk-dwen."

IRRAWADDY AT BHAMO.

April 27th 1837. "We have remained at Bhamo: nothing appears to have been settled below "and the river is reported to be unsafe. It has fallen at least "3 feet since our arrival. Bayfield measured the left channel "yesterday; it is nearly 750 yards wide." * * * p. 97. "The Irrawaddy here is between the "extreme banks a little less than 1½ miles broad, the channel on which Bhamo is situated is the "largest, and is 800 yards across. Two other channels exist of which the west is the smallest, and "carries off least water. The river is a good deal subdivided by sandbanks, but is compared with the "Burrumpooter a confined river. Since our arrival here it has sunk several (say five or six) feet and "no longer looks the noble river it did no our arrival."

Do. p. p. 95, 7.

DESCRIPTION OF RIVER AT BHAMO.

"The river here divides into three channels that on which Bhamo is situated is the widest and "about 700 yards wide; the entire width of the river from bank "to bank is about a mile and a half. There is a difference of sixty "feet between its rise and fall."

Strettell G. W. The Ficus Elastica in Burma Proper, etc., p. 74.

IRRAWADDY ABOVE MOGOUNG RIVER.

Tuesday Feb. 3rd 1874. "The river is divided by the island of Noung Talo partly overgrown "by trees, among which I noted two cocoanuts. The stream to "the right is about fifty yards wide, but too shallow even to ad- "mit of my boats passing up; that to the left is double the breadth, with six feet of water in the "deepest part."

Do. p. p. 170, 1.

MUNTGOUNG DEFILE.

"We now found ourselves passing up a noble gorge whose romantic beauty cannot be surpassad, "even in the annals of poetry itself. The hills echoed forth the "wild cries of my boatmen, cheering one another as they en- "deavoured to stem the fierce current, now purling over the rocky bed casting its spray on either "side in wild delight, and washing our boats from stem to stern. Our progress was slow, and the "pace continued to decrease, until the crew found it was hopeless any longer depending on the their "poles. They jumped overboard with their towing ropes and renewed the struggle,—poor fellows, "nearly been double, and straining every muscle, it was as much as they could do to creep along; "Moung Oung, the Governor's man, suggested we halt and return, but no—there was yet a little fur- "ther distance to be accomplished and I stimulated the boatmen by a promise of an extra day's pay "all round. This had a good effect, and they buckled to their task with double vigour. Another "couple of hours labour brought us to Muntgoung, and here their labours were at an end. Here the "river divides in two great arms, that to the east being considerably larger but the rapids forbids "further progress, though for boats of lighter draft, I believe the channel is navigable for miles "further north."

Do.

Thursday 5th Feb. 1874. "The contrivance my boatmen adopted to prevent the boats descend- "ing with too great velocity was novel but effectual. Midships, "either side, they fastened long ropes to the boat with heavy

Do. p. 172.

"boulders attached, these acted as a drag, and two men at the stern and two at the bow with bam-
"boo poles regulated the course; but although this ingenious precaution materially slackened the
"speed, yet we accomplished in fifteen minutes what took us yesterday over seven hours to per-
"form against stream."

SHUELI RIVER IN UPPER VALLEY.

Elias Ney. A visit to the Valley of the huel on Western Yunan.

February and March 1875. "Throughout its upper valley in the Shan States the "Shueli flows in a wide, but generally well defined, shingly "bed, and with a scarcely perceptible slope between the upper "and lower ends of the valley: the altitude which I have "fixed therefore for the neighbourhood of Nam-Kam (i. e. 2,600 for the river itself) may be "assumed without the probability of any considerable error to be the general altitude of the "whole of its course through the valley. At the ferry within a mile of the town of Nam-Kam "the breadth of the river was about 100 yards, the average depth across some 4½ feet, and the "average surface current about 1½ miles an hour by estimation."

DITTO OR LUNG CHUEN.

Davenport A. Report on Trading Capabilities of country traversed by Yunan mission.

p. 24. "On the second of May (1876) the mission crossed the Lung-chuen river, about 60 "yards in breadth but bringing down nothing like the volume of "water of the Lu-kiang or of the Lan-tsan-kiang."

DISCHARGE OF IRRAWADDY NEAR MANDALAY.

Heathcote Lieut. Yule's mission to the Court of Ava, p. 359.

Col. Yule says "Lieut. Heathcote, however, measured the discharge in the middle of October, "when the surface was ten and a half feet below what was stated "to be the highest level, and nearly thirty feet above the lowest. "The section was taken between the Shwe-kyet-yet and the foot of "the Sagain hills,where the river flows (till very low) in a single and well defined channel. I have "not been able to obtain the elements of the calculation, but the discharge under these circumstances "was calculated by Lieut. Heathcote at 316,580 cubic feet per second. And the areas of the stream "at different heights, as deduced from his section, are

At supposed highest flood	133,800	square	feet.
As observed (ten and a half feet below ditto) ...	105,300	„	„
Supposed lowest level	27,690	„	„

THE SALWEEN.

Richardson Dr., McLeod and Richardson's Journeys page 113.

"From Meinlunghee to the Salween river (called by the Karens Kooloo Khlo, Khlo mean-
"ing river) which is crossed in latitude 18° 16' 22", the dis-
"tance travelled is about 116 miles by the course of the May-
"nema and 109 by the hills; the former we performed in "eight days, whilst the latter occupied eleven; the whole of this portion of the route is very "thinly peopled, provisions difficult to be procured, water and forage for the cattle plentiful, path "generally bad, either over steep hills covered with dense jungle, or along the stony beds of "small mountain streams at the bottom of deep valleys or ravines, and so tortuous that the "actual distance between the two points cannot be much more than half the distance travelled."**

** "The Salween till within 60 or 80 miles of its mouth is said to be one of the most "impracticable rivers in this part of the country, with its bed full of falls and rapids, so as to "render it dangerous in many, impassible in some parts, and its banks abrupt rocky mountains "with very few valleys or spots favorable for the habitation of men; where it is crossed it is about "300 yards wide at this season, and its banks, which are deep, are perhaps 600 yards apart; and "are said to be filled in the rainy monsoon."

RAPIDS OF SALWEEN.

O'Riley E. Report of Mr. O'Riley's Mission to Karennee.

Page 68, para 63. "The result of my enquiries on this subject, with respect to its practi-
"cability from the point of the Kai-ma-pyee down to the Thoung
"Yeen River was so conflicting, that I determined upon descend-
"ing the stream on a bamboo raft to place the matter beyond "all question for the future; but when on the point of executing my intention, a Theet Goung "from Moulmein dissuaded me from it; he had passed down the stream on a small raft at the "period of its lowest supply of water, May and part of June, and he assured me that unless "guided by skilful Karens, who were acquainted with the intricacies of the passage "between the rocks, which at three points between the "Kai-ma-pyee" and the Haat Gyee' "form barriers right across the river, I should most certainly be wrecked, and that even the "Karens who descend the stream during the dry season by a small canoe with two men only, "are frequently stranded when passing, I diverged from the line of route on my return to in-
"spect it.....And from the point of view right across the stream with a breadth of about 120 "yards, mass of boulders and shingle completly closed up the passage except when the water

"forcing its way in eeddies round the base of the larger rocks shewed a greater depth, but no "passage beyond 10 to 12 feet in breadth could be seen to afford drift room for anything larger "than a small canoe."

p. 69, para 64. "From the month of August, the river having received the supply of water "from the higher affluents the stream is navigable to large rafts
Do. do. "down to "Dha-gnu-tseik" River near the Thoung Yeen river "and when at its full, boats and rafts have occasionally passed the great rapids without being "aware of their existence :—this state of the stream however, must be confined to a very short "period during the height of the monsoon only and for any practical purpose of navigation is "useless.

SALWEEN RIVER IN UPPER BURMA.

"Tuesday 29th Decr. 1863." "Came most unexpectedly on the Salween river, which we "found to be a fine broad stream, by no means rapid and
Sconce, Lt. G. C. Journal of Salween Surveying Expedition p. 5. "apparently very deep" * * * p. 5, Decr. 30th. Went down this "morning to the Salween and found it a fine river about 300 "yards wide at present, but evidently during the rains about twice that breadth.

DITTO OR NUKIANG BHAMO—YUNAN ROAD.

p. 24, April 30th 1876. "On the 30th the Mission crossed the Nukiang or Salween, on a "suspension bridge of two spans, about 500 feet in length, the
Devenport. Report on Trading capabilities of Country traversed by Yunan Mission. "iron chains being attached to a stone pier built on the shel- "ving bed of the river at the edge of the deep water channel. "The span over the deep bed was about 270 feet in length, and the one over the bed exposed "during the dry season was about 230 feet in length. This bridge was built during the present "dynasty: under the Ming rule, passengers crossed in a ferry boat capable of holding 100 persons. "It is a deep, rapid, turbid stream, bringing down like the Lantsau, an enormous volume of "water even in the dry season."

DITTO OR SOUK TCHOU LASSA—BATANG ROAD.

"De Chobando apres deux longues et penibles journees de marche dans les sinuosties "des montagnes, et a travers d'immenses forets de pris et de
Huc M. Souvenirs d'un Voyage dans la Tartanie le Tibet, etc. p. 445. "hour on arrive a Kia-Yu-Kiao. Ce village est construit sur "les bords escarpes du fleuve Souk-Tchou qui coule entre deux "montagnes et dont les eaux sont larges, profondes, et rapides. A notre arrivee, nous trouvames "les habitants de Kia-Yu-Kiao plonges dans la desolation: il y avait peu de temps qu'un grand "pont de bois jete sur le fleuve, s'etait ecroule. Deux hommes et trois bœufs, qui se trouvaient "dessus au moment de sa chute, avraient peri dans les eaux. Nous pumes voir encore les debrise "de ce pont, construit avec de grands trones d'arbre: le bois entierement pouvri annoncait que "le pont etait tombe de vetuste."

SHYAL CHU RIVER.

p. 333. "From this snowy group flows northward a very considerable stream, the Shyal Chu, "which was crossed by the Pundit in three separate branches,
Nain Singh Pundit. Account of Pundits Journey in Great Tibet from Leh in Ladakh to Lhasa. Captain Trotter, R. E. "which, although nowhere more than a foot in depth, are said "to be passable only with very great difficulty during the "floods caused by the melting of the snow in the summer months. This stream flows into the "Tashi Bhup Lake whose southern shore is about two miles to the north of the Pundit's road. "From the eastern end of the lake a stream issues whose waters are said ultimately to drain "into the Chargot Lake, from which they emerge under the name of the Nakchukha River, and "flow eastward to the village of the same name which lies on the northern road between Lhàsa "and Pekin."

THE MEKHONG RIVER.

MEKHONG RIVER. DISCHARGE AT BASSAC.

"Le debit du fleuve à Bassac le 5 decembre moment ou les eaux avaient baisse de 9 mètres et où "le courant n'avait plus qu'une vitesse moyenne de 1m, 00 par
Garnier F. Voyage d'Exploration en Indo-Chine p. 225-6-52-94. "seconde a été calculé de 9000 mètres cubes par seconde. "Le 20 septembre jour de niveau maximum atteint par le "fleuve ce debit devait probablement depasser 50,000 mètres cubes. Il serait interessant de con- "stater ce debit au moment du niveau le plus bas et du courant le plus faible. En admettant que "les eaux aient baisse de 3 mètres, encore apres notre depart de Bassac le debit minimum du "fleuve en ce point peut être évalue à 2 ou 3,000 mètres cubes par seconde." p. 226. "Les "mesures prises par M. Delaporte à Lakon situé a deux degrès plus aud nord que Bassac font "resortir en ce point, à la fin de la saison sèche, un debit de 1,350 mètres cubes par seconde."

DEFILES OF THE MEKHONG.

p. 252. " A 1 mile ½ en amont de Pak Monu, le lit du fleuve aux hautes eaux se reduit a 200 " metres de large. Les deux rives sont formees de roches presque à pic. La baisse de l'eau au moment " du passage de M. Delaporte, avait atteint 14 metres ; la vitesse du courant atteignait environ un " demi-mille à l'heure. Deux sondes faites au milieu du fleuve, n'ont pas donné de fond a 100 mètres !

p. 294. " Le lendemain, 5 avril, nous fimes encore assez facilement une dizaine de miles entre deux " rives de plus en plus resserrees ; le fleuve se reduisit a une centaine de metres de largeur, tandis que " la sonde accusait 60 metres de fond. Le courant etait assez peu rapide pour que nous pussions " marcher a la pagaie, au lieu de nous haler le long des rives * * * * *. " Un second rapide Kheng " Khbo, se presente presque immédiatement apres. Je ne trouvai qu un metre cinquante de profondeur " au milieu du fleuve entre ces deux rapides."

Do. p. p. 21, 2, 3, 44, 5. Vol. II.

p. 21. " 23 Aout 1866. Ile de Khon. Petite brise-Brume " le matin. Beau temps le reste du jour. Le fleuve commence " a remonter. Lat. 14° 54'."

p. p. 22-3. Bassac 20 Septembre 1866. Petite brise. Temps assez beau. Voilé. Orages dans le S. E. Le fleuve atteint son niveau maximum."

p. p. 44-5. " Siemlap. 10 juillet 1867. Petite brise. Le temps se decouvre et devient beau " a parter de 10th du matin. Le fleuve a atteint son niveau maximum de l'annee precedente."

ME-KHONG RIVER.

" I measured the river above its junction with the Me Ha where it spreads out into a large " sheet of water during the monsoon. The banks are high, but

MacLeod, Capt. W. C. MacLeod's & Richardson's Journeys p. 80.

" above the spot, as well as at and below the town, the river " is bounded by hills confining the stream within a much nar- " rower bed than where I crossed. The stream at this season is about 450 feet wide ; from bank " to bank it is about 1620 feet ; its rise during the freshes, judging from the high banks, must " be at least 50 or 60 feet. Its bed is rocky ; at one place the stream rushed down with con- " siderable rapidity, but its average velocity I should think is about 3 miles an hour. It is not " at any season fordable, and must be new more than 15 feet deep, but how much more I cannot " say."

DITTO. OR LAN-TSAN RIVER.

" On the 25th April 1876, after a steep ascent we crossed the Lan-tsan river on a suspen- " sion bridge, named Tsi-hung-chias (Rainbow Bridge). Like

Davenport. Report on Trading Capabilities of Country Traversed by the Yunan Mission. p. 23.

" the bridge at Nan-wa tan it is composed of a roadway of " wooden planks laid across large iron chains passing over " stone piers, and attached to the rocks behind. The bridge was provided with stays and al- " though the span was 180 feet the oscillation was unimportant even when riding over it on a " mule." * * * * * " In the fourteenth century iron stanchions were fastened into the " rocks on either side and a rope fastened to them stretched across the river, to which a ferry " boat was attached. The rapidity of the current capsized the boat so often, and so many lives " were lost, that a wooden bridge was in some ingenious manner thrown across the river. Ere " long it was burnt down, whereupon in the year 1502, an iron suspension bridge was built."

ME-KHONG OR OM-TCHOU RIVER.

" Tsiamdo, capitale de la province de Kham, est batie dans une vallée entourée de hautes " montagnes. Autrefois, elle était renfermée dans une enceinte de

Huc. M. Souvenirs d'un Voyage dans la Tartarie, le Thibet &c. pp. 453-4.

" remparts en terre aujourdhui écroulés de toutes parts et dont on " enlève journellement les débris pour réparer les plates formes des " maisons. Tsiamdo du reste, n'a guere besoin de fortifications artificielles ; elle est suffisament " protégée par deux fleuves, le Dza-Tchou et le Om-Tchou, qui après avoir coulé, l'un a l'est, et l'autre " a l'ouest de la ville, se réunissent au sud, et forment le Ya-Long-Kiang qui traverse du nord au midi, " la province de Yun-nan et la Cochin-Chine, et se jette enfin dans la mer de Chine. Deux grands " ponts de bois, jétés l'un sur le Dza-Tchou, et l'autre sur le Om-Tchou, à droite et à gauche de " la ville, conduisent a deux routes parallèles, nommeès, la première, route du Sse-Tchouen, et la " seconde, route du Yun-nan. Les couriers qui font le service des postes de Lha-Ssa à Peking, et " tous les employés civils ou militaires du gouvernment chinois, sont obligès de passer sur la route " du Sse Tchouen ; cellē de Yun-nan est presque habituellement déserte."

THE SANPO

p. 218. " The Sanpo, or Thibet river, supposed by M. D'Anville, to be the same with that which is calied, in the lower part of its course, the river of Ava : but we have not the least doubt at present, of its being the same with the Burumpooter, which enters Bengal on the north-east, and joins the Ganges near the sea. I traced it in 1765 to about 400 miles above the conflux

Rennell, Major J. Memoir of a map of Hindostan or the Mogul Empire.

that is as high as the latitude of 26°, longitude 91°; where the Bengal districts end, and those of Assam begin; but I was not permitted to go any higher. However, some few Europeans, engaged in the Goalparah trade, and among others, M. Chevalier, the late Governor of Chandernagore, by permission of the King went as high up as the capital of Assam about the year 1762: but was under a considerable degree of restraint, with respect to making remarks, either on the course of river, or on the country. As M. Chevalier, however, went on a very large embarkation, we are convinced that the river is navigable for large boats, through a space about equal to the distance from Buxar to the sea; that is, between 600 and 700 miles. It may probably be navigable much higher up; though its navigable course cannot be equal to that of the Ganges; this flowing, chiefly through a level country, and the Burrumpooter through a mountainous one. I have placed the capital of Assam, Gherogoung, (or Kerganu) 160 G. miles nearly E. by N. from Goolparah, according to the report of the Assamers. They also informed me, that the Burrumpooter has a very long course previous to its entering Assam; and that it comes from the N. W. through the Thibet mountains. Now the Lama's map of Thibet in Du Halde, describes the course of the Sanpo, to within 120 G. miles of the assumed situation of the capital of Assam and still nearer to some parts of the Burrumpooter that are known, and have been described by the Assamers. These facts together with those respecting the Ava river and Now-kian, establish (I think) the strongest presumptive proof possible, of the Sanpo and Burrumpooter being one and the same river under different names, and positive proof can never be obtained, but by actually tracing them; a circumstance unlikely ever to happen to any Europeans or their dependants."

p. 256. "These rivers, [the Ganges and the Bramaputra] which a late ingenious gentleman
Do. "aptly termed sisters and rivals (he might have said twin-sisters
"from the contiguity of their springs) exactly resemble each othe
"in length of course, in bulk, until they approach the sea; in the smoothness and colour of their "waters; in the appearance of their borders and islands; and finally in the height to which their "floods rise with the periodical rains. Of the two, the Burrumpooter is the largest but the differ- "ence is not obvious to the eye. They are now well known to derive their sources from the vast "mountains of Thibet; from whence t ey proceed in opposite directions and the Burrumpooter by "the east; both pursuing the early part of their course through rugged vallies and defiles, and "seldom visiting the habitation of men."

SANPO RIVER.

"On the 9th of November after descending an easy hill, we arrived on the banks of Sanpoo. It
Bogle G. Narrative of mission to Tuibet. "is here about the breadth of the Thames at Putney. The channel
"is not fordable. As the river is far from being rapid, we crossed
"it without losing much ground"

"After crossing the river, we rode northwards over a large sandy bank, which is overflowed in "the rainy season, and entered a valley which opens upon the Sanpoo."

DITTO.

"From this town we descended down to the sandy shore, and found a large ferry-boat ready
Manning T. Narrative of journey to Lassa, p. 251. "to waft us over the stream, whose breadth here was consi-
"derable."

DITTO.

p. p. 340, 341. "On the 27th November reached the Samaye Monastery, which lies on the
Nain Singh. Account of the pundit's journey in Great Thibet from Leh in Ladakh to Lassa and of his return to India via Assam by Capt. H. Trotter, R. E. "right bank of a small small tributary of the Burrumpootra about
"2 miles before it falls into the great river."

"From Sama-ye the Pundit travelled down the course of the Brahmaputra for two marches, "passing several small tributaries en route. He crossed the great river in a boat on the 30th of "November. In this portion of its course it is known either as "Tsanpo" or "the river," or by "the name of Tamjun Khà. At this, now the lowest known part of the course of Brahmaputra in "Great Thibet, the Pundit estimates the width of the river at 500 yards. The stream was very "sluggish, its current near the banks being no more than two-thirds of a mile per hour. Its depth "was no where more than 20 feet."

"The valley through which the river flows was here several miles across; on the left bank of "the stream was a stretch of sand fully 1½ mile in breadth, the whole of which is said to be under "water in the months of May, June and July; during which season the river is much flooded, both "on account of the increase of water from the then rapidly melting snows as well as from the rain, "which falls in considerable quantities from April to June. The river is here no longer used for "irrigation, as above Shigatze, but all the smaller streams which issue from the mountains on the "north and south are thickly bordered with cultivated land."

"The Pundit left the river near Chetang, from which point he states that its general course "is visible due east for a distance of 30 miles, after which it encounters a range of mountains "which cause it to diverge in a south-easterly direction. By taking bearings to, and fixing the

" position of some peaks on this side of which the river is said to flow, he fixed the course of the
" river approximately for a very considerable distance below where he quitted it. The course of
" the river thus determined is very fairly accordant with that shewn on Du Halde's map of Thibet."

DITTO.

March 28th 1877. " The following is some new information which should confirm the identity.
" of the Yar-kin-tsang-po river of Thibet with the Brahmaputra
Desgodins. The Abbe. Notes on Thibet P. A. S. B. for Jany. 1878 p. p. 24 25. " An Old Llama related to me yesterday that in his youth he had
" travelled a great deal and had visited nearly the whole of Thibet.
" He had followed the great river from its source in or near the Lakes of Tso-ma-pang (Manasa-
" rowar), which are situated in the western part of the province of Ngare, the most western pro-
" vince of Thibet, and while making his pilgrimages of devotion he had arrived as far as the fron-
" tiers of the savage tribe of Shopas. He said that at the distance of some days march from
" Lhassa, the river turns towards the south and making a long bend passes through the Thibetan
" district of Hiayul governed by the Kalun Doung of Lhassa, a very populous and rich district
" which is situated just to the north of the Lhopas. The river enters the country occupied by
" this wild tribe and passes through perpendicular rocks, precipitous and bare, without paths and
" over which the only passage is by means of bad ladders made of stems of climbing plants. After
" a certain course through the Lhopas country, the river falls perpendicularly from the top of a
" rock into a valley the name of which he did not know. The heightof the fall is so great that
" it makes one giddy.

THE BRAMAPUTRA AND ITS TRIBUTARIES.

BRAMAKUND.

" The Burrumpootra or Lohit, accessible only as far as the reservoir of the Bramakund
" (unless perhaps to the hill Mishmees) takes its original rise
Neufville, Lt. Memoir of a survey of Assam and neighbouring Countries executed in 1825-6-7-8. Lieut. Wilcox. " very considerably to the eastward, issuing from the snow at
" one of the loftiest of the ranges; thence it falls a mere moun-
" tain rivulet to the brim of the Bramakund."

DITTO.

" The river is here but forty to sixty yards wide. I got meridian altitudes of two stars,
" which gave the latitute 27° 54' 52" 4. Dilling the point of de-
Wilcox and Burlton. Do. Do. p. 33. " parture, is fixed by a bearing on the bend of the river below the
Kund * * *."

DITTO.

" The breadth of the bed is a good hundred yards, but the stream at this season is confined
" to the fifty yards near the south bank, the remainder being
Griffiths W. Journels of travels in Assam, Burma, etc., p. p. 26, 27. " occupied by rocks *in situ*, or boulders and sand : the edge
" of the north bank is occupied by stunted Saccharum. The
" appearance of the water is characteristic of a greyish green tinge, giving the impression of great
" depth. It is only here and there it is white with foam its general course being rather gentle.
" It is in various places encroached upon more or less by the rocks forming its bed, some of
" which are quite porpendicular.
p. 27. " The water mark of floods visible on some of the rocks, is probably eight feet
" above that of this time of the year. (October 22nd.)

DITTO.

" We had now arrived at the famous Bramakund, and I was greatly disappointed to find
" that my expectations—gathered from hearsay—of its scenic
Cooper T. T. The Mishmee Hills p. 179. " grandeur were not realized. I had pictured a gloomy gorge
" from which I expected to see the Bramapootra pouring its waters into a large pool or lake.
" Instead of this the Bramapootra river simply debouched from a low range of hills in a noisy
" turbulent stream, and turning sharp from the north flowed quietly eastwards. Its rocky banks
" were not two hundred feet in the perpendicular anywhere. The Bramakund or sacred spring—
" from which the neighbourhood takes its name—was nothing more than a tiny streamlet trickling
" down the precipitous cliff and falling into a deep basin, formed by a point of rock" * * * * * *.

DITTO.

" Every one in Assam knows the fall of Bramakund whither the heathen resort as pilgrims.
" M. Bernard has often spoken to me of it as a fall remarkable
Desgodins The Abbe notes on Thibet P. A. B., for Jany. 1878, p. p. 25-4. " for its height, the force of its volume of water, and the hollow
" it scoops out in falling. The southerly position attributed by
" my confrere to this vast fall, and the northerly position given to it yesterday by the Llama,

"induce me to believe that the fall at Bramakund must be precisely the fall of the Yar-kin-tsang-
"po which then becomes the Brahmaputra, the latter being navigable almost immediately after
"this addition."

BRAMAPUTRA RIVER.

"On the 28th September (1869), the Brahmaputra had fallen some twelve feet below its highest
"summer level; indeed the previous few days of fine weather and
Cooper T. T. The Mishmee Hills. p. p. 125-6. "rapid fall of the river, induced a hope that the dry season had
"commenced, but on the 29th about midday, it commenced rain-
"ing heavily, and by the following morning the Brahmaputra had again reached its highest summer
"level, having risen, in the space of eighteen hours, more than twelve feet, a clear proof that the
"great floods accompanying the summer rise of this river are due to the rain, and not the melting of
"the snow on the Himalayas, as many suppose."

DIBONG RIVER.

"On the 14th December—the width of the river was reduced to between twenty and thirty
"yards, and as it was not above knee deep, it appeared not un-
Bedford Capt. Wilcox narrative, p. 14. "likely to be near the head of this branch.

DEHONG RIVER.

"The river Dehong leaves the hills about twenty miles above its junction with the Burrum-
"pootra, and is navigable during the high summer rise to this
Cooper T. T. The Mishmee hills, p. 118. "point, above which, according to some Abors whom I met at
"Sudiya, it is a deep, swift stream broken by rapids. Its appearance so far as I ascended, was
"imposing; it was a quarter of a mile wide at the narrowest point flowing with a deep, swift
"current. The same Abors further stated that the Dehong came from a long distance in the Lama
"country, and was called the "great river" by the Lamas and people of Thibet."

DITTO.

Near Shiku. "There is generally a small bed of stones under the base of the hills, found
"alternately on either bank, which would add one hundred to two
Wilcox Lieut. R. Memoir of Survey of Assam, etc. p. p. 54, 5 and foot note. "yards to the breadth when the river is full. At present the breadth
"of water was 200 yards."

p. 55. "The breadth of the river was reduced at this point to one hundred yards, and it
"was still mild and tranquil but the form of the hills gives rise to the expectation of immense
"depth." * * * "The river partook of the same kind of features as we proceeded: the water's
"edge was bounded by smooth perpendicular rock, under which we advanced by poling against
"the small projections and crevices, but after getting over a distance of two or three miles the
"foam of a rapid became visible as we turned a corner and here we soon found our labours were
"at an end. A stone bed projected from the east bank, few of the rounded blocks of which were
"less than two or three feet in diameter, and many were of much larger size. The rapid could
"never be passed on the descent, even if it were possible to get the boat up it; and as to car-
"rying the canoe, that was unpracticable over blocks of stone of such size. We advanced as far
"as it was possible on the stone bed, and from its farther end climbed up the rock to overlook
"the river. The next reach was from the west and the water quite smooth to a considerable
"distance, the hills high and equally steep to the waters edge."

Foot note.—"A very simple calculation shows us that, for the undiminished discharge of
"50,000 cubic feet per second and a supposed velocity of only three miles, the depth required
"is only thirty seven feet, Mr. Klaproth's objection to the size of the river appears then not
"well founded."

SUBANSIRI RIVER.

"Having arrived at its mouth on the 28th November I commenced my survey on the
"following day, but I was disappointed to find my further progress
Wilcox, Lt. R. Memoir of a Survey of Assam etc., p. p. 8. 9. "impeded on the sixth day by rapids, occasioned by the accu-
"mulation of round stones brought down from the hills, where,
"from its mouth, I had got but twenty-two miles latitude to the north."

p. 9. "Of the Subanshiri they could only tell me that it is divided above into three branches.
"It is called by them Kamla, and the principal branch rises in the north or north-west."

p. 9. continued. "The Subanshiri river is scarcely inferior to the Ganges at Allahabad in
"December. I found the discharge at mouth 16,000 cubic feet per second, and up to the hills its
"tributary streams are few and of little consequence. I think there is no doubt of its being the
"Amehu of Du Halde and Rennell."

DITTO.

"The volume of water down the Subanirie is said to favour the idea of its junction with the
"Sanpu and further careful observations are now being made by
Thuillier Majr. Genl. H. L. on the connection of the Bramaputtra and Sanpu. P. A. S. B. Tan. 1878. p. 27. "Lieutenants Harman and Woodthorpe R. E. to ascertain
"whether the Subansiri exceeds the capacity of the Dihong or
"of the Dibong the former of which has long been held by
"English Geographers to be the real outlet for the Sanpu into the Brahmaputra near Sadiya."

" It was unfortunate that the journey taken by the explorer Nain Singh below or south " of Lhassa was too far west to solve this interesting and long pending doubt, but the statement " made by the author of the paper now read, certainly favored the assumption regarding the " probability of the Sabansiri theory. The question was, however, altogether conjectural at present " and must remain so until more conclusive evidence is produced as to the real course of the " Dibong as well as of the Subansirie upwards, or other native explores can penetrate downwards " from Lhassa to the head of the Assam valley through the Abor and Miri tribes inhabiting " that remarkably unknown and untrodden region."

BRAMAPUTRA RIVER.

" Immediately below Gowahti hills confine the Burhumputra to the breadth of one thousand " two hundred yards, the narrowest in its course through As- " sam; there in the rainy season boats are necessitated to be " moored till a westerly breeze springs up of sufficient force to " carry them through the narrow strait; but there is often " great difficulty even where the river flows in an open bed."

Wilcox Capt. Captn. Boileau, Pemberton's Report on Countries on Eastern frontier of British Territories. p. 151.

DITTO.

" Wilcox deduced from measurements of the Dihong, and of the united Burumpooter at " Goalpara that after deduction of the former as foreign supply " there remains a low water discharge of 90,188 cubic feet per " second as the drainage of 15·3 square degrees of surface; and he calculated from this that there probably might be a discharge of 180,000 feet in the Irrawaddy at Prome during the dry season."

Wilcox, Yules Court of Ava. Appendix. p. 359.

BRAMAPUTRA SURVEYS.

" The breaking out of the Burmese War led to the acquisition of much valuable geographi- " cal information in the direction of the north east frontier of " Bengal, and of that vast unknown region beyond, which then " as now, was delineated only from the maps of D'Anville. " Captain Bedford and Lieutenants Wilcox and Burlton were sent to explore the Brahmapootra " towards its source in 1825, under instructions from Colonel Blacher then Surveyor General. " Burlton surveyed the Brahmapootra as far as Sudiya. Bedford went up the rivers Dihong (Sanpu) " and Dibong until he was stopped by wild frontier tribes, and Wilcox made one journey beyond " the frontier up the Brahmapootra valley, and in another penetrated to the banks of the Irrawaddy. " Captain Boileau Pemberton surveyed the territory of Munipoor and surrounding country, and " portions of Cachar, between 1825 and 1830; and from 1830 to 1837 Dr. Richardson and Captain " Macleod made exploring journeys from Moulmein to Ava and to Kiang Hung near the Chinese " frontier. To this day no explorer has succeeded in adding in any appreciable degree, to the know- " ledge conveyed by the discoveries of Bedford and Wilcox, as regards the region beyond our north- " east frontier and towards the sources of the Brahmaputra and Irrawaddy. Captain Pemberton's " exceedingly valuable large map compiled from the route surveys of all these officers was litho- " graphed at Calcutta in 1838."

Markham C. R. A memoir on Indian surveys p. p. 83. 4.

APPENDIX III.

RAINFALL TABLES FOR STATIONS IN BURMA.

Rainfall at Akyab.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1845	..	..	..	..	..	..	..	..	..	..	..	..	..
1846	..	..	..	..	..	..	..	..	..	..	..	..	..
1847	..	..	..	..	..	..	..	..	..	..	..	..	..
1848	..	..	..	..	..	..	..	..	..	..	..	..	..
1849	..	..	..	..	..	..	..	34·25	19·50	2·00	0·80	0·20	56·75
1850	1·50	0·10	..	0·10	3·95	66·90	44·67	57·75	48·20	26·45	4·50	..	254·12
1851	..	..	..	..	11·69	59 10	22·87	27·32	17·11	14·85	..	2·10	155·04
1852	..	..	2·54	..	..	..	..	..	..	..	..	..	2·54
1853	..	..	..	..	..	..	..	..	..	..	..	..	..
1854	..	..	..	..	..	..	..	..	..	..	..	..	..
1855	..	..	..	..	..	..	..	..	..	..	..	..	..
1856	..	..	..	..	..	..	..	..	..	..	..	..	..
1857	..	..	..	..	..	..	..	..	..	..	..	..	..
1858	..	..	..	..	..	..	..	..	..	..	..	..	..
1859	..	..	..	..	..	..	..	..	..	..	..	..	..
1860	..	..	..	..	6·70	97·60	47·10	46·20	25·67	27·60	22·30	..	273 17
1861	..	..	0·50	1·77	45 10	63·00	53·90	30·10	16·20	21·80	..	0·25	232·55
1862	..	..	0·50	5·70	13·70	72·60	56·50	55·70	18·60	25·70	..	..	247·00
1863	..	..	..	3·40	7·10	80·00	50·80	57·60	19·20	14·60	8·20	..	240·90
1864	..	3·60	2·10	..	3·80	54·50	87·50	30·70	23·80	15·80	0·10	..	221·90
1865	..	..	.	2·40	30·30	35·20	58·30	24·10	26·90	9·00	5·10	..	191·30
1866	..	0·40	0·70	0·20	2·10	37·20	29·60	46·70	21·10	7·30	0·00	..	145·80
1867	0·40	..	..	1·30	24 30	58·00	63·80	25·00	32·00	1·20	13·10	0 10	199·80
1868	..	..	0·20	1·55	3 50	66·20	48·20	40·90	22·60	14·50	16·00	..	208·65
1869	..	0·05	..	2·00	4·70	56·10	55·40	37·10	27·75	5·40	..	..	188·50
1870	0·50	..	..	3·30	15·70	31·80	45·00	27·87	36·70	14·60	1·70	0·31	177·48
1871	..	..	0·80	..	23·60	65·50	45·10	27·10	22·40	14·60	..	0·70	199·80
1872	0·20	..	..	0·10	16·20	54 30	42·20	35·30	59·10	5·30	7·00	0·20	219·90
1873	..	..	..	1·70	14·20	39·80	39·80	43·80	20·80	18·00	1·50	..	179·60
1874	..	..	1·60	..	8·03	36·20	13·50	43·40	14·57	15 97	2·07	..	135·43
1875	..	..	..	0·15	15·32	40·50	52·03	20·60	20·80	2·40	..	..	150·40
1876	..	..	..	0·09	7·19	33·05	56·15	21·93	30·74	5·14	7·27	0·37	161·93
1877	..	..	..	..	2·61	40·24	56·65	40·99	23·22	3·95	8·98	..	176·64
Average ..	0·06	0·225	0·36	1.311	13·44	52 35	49·84	36·39	25·675	12·27	5·22	0·107	197·27

Rainfall at Kyoukphyoò.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	0·30	..	..	4·40	12·80	28·80	55·20	24·80	19·30	8·90	2·10	..	156·60
1871	..	..	1·40	..	19 90	50·70	51·60	31·30	19·80	17·50	0·70	0·20	193·10
1872	..	1·00	..	..	13·10	37·60	40·80	46·10	13 10	7·20	1·80	..	160·70
1873	..	..	..	..	7 20	29·60	32·70	53·90	17·10	10·40	0·70	0·10	151·70
1874	..	..	1·70	..	5·50	40·70	13·30	55·80	23·85	21·30	3·20	..	165·35
1875	0·10	..	2·00	4·10	14·60	62·00	69·10	31·00	26·30	9·40	1·90	..	220·50
1876	..	..	0·00	..	8·33	22·47	55·39	25·89	17·27	6·24	8·18	..	143 77
1877	..	..	..	..	1·09	35·05	63·05	72·07	32·03	9·04	16·09	..	228·42
Average ..	0·05	0.12	0·64	1·06	10·32	38·37	47·64	42·61	21·09	11·24	4·33	0·04	177·52

Rainfall at Sandoway.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1860	..	..	..	..	18·18	48·6	55·79	31·49	45·31	11·58	2·07	..	213·02
1861	..	..	..	..	18·62	45·06	52·05	49·03	39·35	20·40	..	..	225·11
1862	..	..	1·2	0·40	14·25	47·40	74·65	50·75	11·60	22·55	..	..	222·80
1863	0·70	..	..	5·00	13·20	63·90	57·45	68·95	24·91	19·00	1·40	..	254·51
1864	..	..	..	..	5·80	71·65	82·56	54·30	27·40	11·95	..	..	253·66

Rainfall at Sandoway—continued.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1865	..	..	..	..	..	..	..	..	..	..	..	..	..
1866	..	..	..	..	14·90	80·40	38·50	60 80	34·30	11·00	5·30	0·15	245·35
1867	..	..	..	1·00	21·30	33 40	48·80	26·50	40·15	2·18	6·15	1·30	180·78
1868	..	..	0·70	0·85	14·85	65·90	51·00	87·45	17·95	11·75	2·70	0·00	253·15
1869	..	0·55	..	0·30	3·65	84·85	52·45	26·10	15·15	8·30	..	..	191·35
1870	..	..	..	2·40	30·60	34·30	97·40	40·26	20·88	10·18	..	..	236·02
1871	..	..	1·20	..	28·10	64·60	60·30	47·50	18 80	9·40	..	..	229·90
1872	..	1·00	..	..	22·00	39·80	55·50	51·30	18·40	6·10	1·00	..	195·10
1873	..	..	..	..	26·10	53·10	57·90	57·50	23·40	10·20	7·60	..	229·80
1874	..	..	0·15	..	12·09	36·09	15·00	57·10	9·40	20·40	0·50	.	148·55
1875	0·50	..	0·20	2·50	9·80	46·90	81·80	35·50	35·60	17·30	0·30	..	230·40
1876	..	..	..	..	6·22	26·24	65·92	24·44	18·87	7·16	4·58	0·02	153·46
1877	..	..	..	..	2·05	60·02	74·09	74·15	22·05	8·30	8·83	..	249·58
Average ...	0·07	0·09	0·20	0·73	15·15	53·06	59 95	49·63	24·91	12·20	2·38	0·08	218·38

Rainfall at Thayetmyo.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	..	0·30	...	0·50	12·30	6·30	7·80	5·70	6·10	2·60	...	...	41·60
1871	..	..	...	0·20	8·40	7·70	9·60	10·70	12·00	5·30	0·70	...	54·60
1872	..	..	...	0·10	6·50	11·70	7·90	8·00	10·20	2·90	1·20	...	58·10
1873	..	..	...	...	6·20	7·60	6·40	10·15	4·60	4·00	4·00	...	42·95
1874	..	..	1·00	...	8·90	5·00	5·70	11·80	7·30	10·10	0 50	0·10	50·40
1875	..	..	..	3·50	6·60	8·10	16·20	8·10	10·30	5·20	0·30	...	58·80
1876	..	..	...	...	0·91	7·46	9·07	6·73	5·51	3 51	5·19	...	39·28
1877	..	..	...	0·40	3·88	12·52	9·91	20·13	4·25	9·56	1 90	...	62·55
Average ..	..	0·04	0·12	0·59	6·71	8·29	9·18	10·24	8·72	5·39	1·72	0·01	51·03

Rainfall at Prome.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	...	...	...	1·10	8·70	4·30	12·40	7 50	8·30	3·50	...	...	45·80
1871	...	...	0·10	...	13·40	14·20	7·70	6·60	9·50	11·40	...	...	62·90
1872	...	...	...	1·30	4·90	9·60	12·60	22·90	12·70	7·30	0·50	...	71·80
1873	...	...	...	...	5·40	12·40	14·00	37·70	6·90	8·70	3·20	...	88·30
1874	...	...	...	...	6·95	5·18	1·25	7·25	2·07	5·00	0·05	...	27·75
1875	...	...	...	2·50	3·00	7·70	11·50	6·20	6·00	7·00	AA	...	43·90
1876	...	...	...	0·58	4·36	12·16	8·33	10·37	10·22	2·19	3·16	...	51·37
1877	...	...	...	1·27	2·62	11·95	7·15	17·15	6·08	6·59	7·03	...	59·84
Average ...	...	...	0·01	0·84	6·17	9·69	9·37	14·46	7·72	6·46	1·74	...	56·46

Rainfall at Henzadah.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	...	...	...	...	16·03	8·94	19·61	11·65	10·31	2·31	0·68	..	69·53
1871	...	...	...	...	10·30	26·00	16·30	14·20	13·00	7·00	..	..	86·80
1872	...	...	...	0·30	4·50	11·50	17·20	18·80	9·40	2·40	1·40	..	65·50
1873	...	...	...	0·10	2·40	12·90	15·40	15·60	13·40	4·80	5·60	..	79·20
1874	...	...	...	0·40	6·60	15·20	9·00	19·10	8·90	4·70	0·80	..	64·70
1875	..	...	...	4·03	10·26	16·14	32·84	22 63	12·35	5·33	1 37	..	104·98
1876	...	...	...	0·27	9·39	15·29	21·42	10·96	9·91	4·78	4·45	..	76·47
1877	...	...	...	...	0·75	19·26	18·02	21·66	9·60	7·05	1 99	..	78·33
Average ...	...	...	...	0·64	7·53	15·65	18·72	16·83	10·86	4·79	2·03	..	77·06

Rainfall at Rangoon.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	0·50	0·50	..	3·20	16·00	11·15	12·30	12·80	14·70	6·50	0·80	..	78·46
1871	..	..	0·50	..	27 20	32·40	27·20	27·80	19·20	9·60	..	..	143·40
1872	..	..	0·10	1·00	8·70	18·60	24·90	27·30	21·10	9 60	1·20	..	112·50
1873	..	..	..	3·00	2·00	28·90	35·70	18·20	20·10	16·30	6·00	..	131·10
1874	..	..	..	..	7·85	11·82	7·38	15·45	13·28	12·52	0·75	..	69·05
1875	..	..	..	4·90	16·90	15·50	17·60	9·50	7·90	3·10	5·90	..	79·30
1876	..	..	..	1·41	17·53	12·72	25·95	16·58	14·70	3·50	5·62	..	98·01
1877	..	..	..	..	1·10	27·10	22·34	21·36	13·87	11·33	4·34	..	101·44
Average ..	0·06	0·06	0·075	1·69	12·27	19·77	21·67	18·56	15·61	9·05	2·83	..	101·65

Rainfall at Bassein.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	1·90	..	..	1·40	12·80	14·80	18·50	21·60	8·90	6·20	1·00	..	87·10
1871	..	...	1·00	0·30	11·30	26·00	17·30	14·40	14·00	8·10	0·70	0·20	93·40
1872	..	..	..	1·10	8·10	11·20	15·80	15·90	12·40	7·50	1·70	..	73·70
1873	..	..	..	2·70	5·90	6·70	31·10	18·50	27·10	8·10	8·20	..	108·20
1874	..	..	..	..	..	..	16·00	36·90	7·00	8·20	0·90	..	69·00
1875	1·92	..	..	1·92	10·28	24·27	28·95	15·28	22·09	10·67	1·02	..	111·40
1876	..	..	..	2·17	9·47	13·07	35·16	17·50	16·69	7·52	2·60	..	104 18
1877	..	..	..	..	6·31	33·85	31·93	33·07	8·45	6·56	2·11	..	123·18
Average ..	0·48	..	0·14	1·20	8·02	16·23	23·72	21·75	14·58	7·85	2·28	0·02	96·28

Rainfall at Tavoy.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	..	..	..	0·60	22·10	22·40	49·70	49·80	34·50	5 40	0·90	..	185·40
1871	..	7·00	1·30	1·30	30·10	38·50	44·40	33·70	59·30	14·30	..	..	229·90
1872	..	..	..	0·60	17·00	25·80	44·60	48·60	32·70	7·90	2·20	..	179·40
1873	..	..	..	..	2·70	37·30	47·90	22·10	44·20	9·10	3·40	..	166·70
1874	..	0·90	0·60	11·82	34·70	35·45	22·12	65·85	14·28	24·50	..	0·20	210·42
1875	..	0·05	..	6.40	10·70	40·88	63·90	42·05	43·65	21·17	1·10	..	229·90
1876	..	..	..	3·10	27·47	29·22	62·27	26·74	19·51	6·53	1 08	..	175·92
1877	..	..	0·05	1·15	18·52	54·32	54·22	56·04	12·52	6·77	2·18	1·04	206·81
Average ...	..	0·99	0·24	3·12	20·41	35·48	48·64	43·11	32·58	11·05	1·36	0·15	198·05

Rainfall at Mergui.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	...	...	...	...	...	...	...	...	...	...	...	...	...
1871	...	5·50	10·00	3·60	24·60	45·30	23·90	34·60	30·10	16·70	0·10	...	194·40
1872	0·50	...	0·80	3·30	7·40	18·80	30·30	35·60	27·40	10·50	0·80	...	135·40
1873	...	...	...	2·30	5·60	24·90	31·30	31·30	21·50	11·50	7·40	...	135·80
1874	1·40	2·52	3·12	9·08	19 20	30·22	13·12	31·18	17·10	19·18	1·02	1·08	148·22
1875	0·10	0·10	0·02	1·20	16·28	30·18	30·62	22·65	15·95	13·65	1·22	0·03	132·00
1876	0·07	0·82	0·03	11·11	26·40	20·07	45·20	22·65	29·06	14·11	1·17	2·05	172·74
1877	...	0·07	3·54	0·60	15·99	29·38	30·57	29·29	15·58	9·23	1·79	0·02	136·06
Average ...	0·295	1·29	2·50	4·45	16·49	28·40	29·28	29·61	22·38	13·55	1·92	0·45	150·66

Rainfall at Tounghoo.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	..	..	..	0·50	12·60	10·80	16·10	11·40	6·60	6·50	0·20	..	64·70
1871	..	..	0·30	..	15·00	20·10	19·10	18·40	17·00	10·30	0·10	..	100·30
1872	..	..	..	0·10	7·60	15·30	16·20	15 30	6·90	9·20	1·30	..	71·90
1873	..	..	..	..	4·20	7·90	7·80	21·30	9·30	8·10	2·40	..	61·00
1874	..	..	..	..	7·70	7·60	7·40	17·10	11·30	8·80	1·10	..	61·00
1875	..	..	..	5·60	4·82	9·12	22·48	27·03	10·50	13·00	..	0·50	93·05
1876	..	..	..	1·62	3·16	5·32	23·65	12·81	14·73	0·78	2·81	..	64·88
1877	..	..	..	0·02	0·86	18·32	22·80	15·19	8·89	7·59	4·03	..	77·70
Average ...	..	..	0·04	0·98	6·99	11·80	16·94	17·31	10·65	8·03	1·49	0·06	74 31

Rainfall at Shweygheen.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1870	0·10	2·40	1·40	4·20	31·00	37·30	43·10	30·20	18·50	13·60	2·00	..	183·80
1871	..	..	1·30	1·90	30·10	33·50	45·40	42·60	30·50	15·80	0·80	..	201·90
1872	..	..	2·10	1·70	15·90	36·40	30·80	29·00	9·60	11·30	1·00	..	137·80
1873	..	..	..	2·10	2·20	19·80	19·90	40·30	15·40	9·50	4·70	..	114·10
1874	..	..	1·10	..	14·00	38·30	12·70	45·80	12·40	17·70	..	..	142·00
1875	..	..	..	..	17·30	41·30	55·70	22 00	26·10	8·30	1·40	..	172·10
1876	..	..	..	1·11	11·42	19 35	28·18	26·84	20·26	2·15	3·17	..	112·48
1877	..	..	..	..	1·38	38·09	42·00	34·07	24 79	8·24	3·57	..	152·14
Average ...	0·01	0·30	0·74	1·376	15·41	33·01	34·72	33·91	19·66	10·82	2·08	..	152·04

Rainfall at Maulmain.

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total of each year.
1850	..	..	..	3·90	4·90	31·50	42·00	13·90	26 30	1·70	..	..	124·20
1851	..	..	..	1·70	20·50	38·80	30·10	27·20	28·70	7·80	..	..	154·80
1852	..	..	..	..	17·50	26·30	30·40	17·20	29·50	3·40	..	..	124·30
1853	..	..	..	0·20	15·30	29·80	57·30	18·10	26·50	4·50	..	..	151·70
1854	..	..	..	7·00	18·50	25·20	48·70	49·50	35·60	11·95	..	..	196·45
1855	..	..	..	2·50	21·55	39·75	48·20	36·20	31·48	6·52	..	..	186·20
1856	..	..	..	6·02	19·95	21·38	33·42	41·65	30·45	1·20	..	..	154·07
1857	..	..	..	2·48	28·27	33·00	35·25	63·80	20·00	10·30	..	..	193·10
1858	..	..	..	2·80	21·00	34·55	45·60	57·90	26·57	2·10	..	..	190·52
1859	..	..	..	3·45	18·95	36·05	28·75	32 05	24·75	11·85	..	..	155·85
1860	..	..	..	7·10	15·85	29·50	35·65	32·25	21·05	3·90	..	..	145·30
1861	..	..	..	4·60	17·85	25·05	33·40	35·00	28·60	19·70	..	..	164·20
1862	..	..	..	1·30	29·40	37·90	46·30	61·60	21·40	10·40	..	..	208·30
1863	..	..	..	9·00	33·00	56·12	50·55	71·48	30·30	12·15	..	..	262·60
1864	..	..	..	..	12·40	56·85	60·00	31·75	46·10	3·80	..	..	210·90
1865	..	..	..	0·40	26·75	51·15	68 35	72·20	38·70	12·80	8·65	..	279 00
1866	..	..	0·40	..	37·80	53·70	47·95	60·70	36·10	8·80	1·90	..	247·35
1867	..	..	..	1·70	21·95	32·40	32·95	38·70	63·85	5·70	0·60	..	197·85
1868	..	..	..	6·60	15·30	43·95	31·30	61·50	36·75	10·10	5·70	..	211·20
1869	..	..	..	2·65	11·45	64·95	48·75	35·45	16·80	9·55	0·25	..	189·85
1870	..	1·00	..	2·00	22·15	29·45	46·85	59·25	15·00	8·85	0·90	..	185·45
1871	..	..	..	3·25	36·00	55·45	43·40	51·50	39·15	17·10	..	..	245·85
1872	..	0·50	..	2·80	35·55	27·75	46·70	47·80	21·50	1·25	..	..	183·85
1873	..	..	0·15	8·55	15·20	38·05	61·45	34·75	44·30	8·10	1·15	0·25	212·85
1874	..	..	1·70	0·85	30·15	31·95	45·20	54·50	25·80	16·25	0·60	..	207·00
1875	..	..	0·10	5·65	17·20	52·95	48·10	39 15	54·60	9·05	2·75	..	224·55
1876	..	..	..	1·06	14·46	36·22	60·39	36·18	38·61	1·73	1·69	0·02	188·35
1877	..	..	0·45	0·04	11·33	43·54	34·63	47·64	20·30	6·76	..	..	164·69
Average ...	..	0·05	0·10	3·13	21·08	38·72	44·16	43·89	31·31	8·12	0·87	0·01	191·44

APPENDIX IV.

EXTRACT FROM DR. ANDERSONS METEOROLOGICAL OBSERVATIONS IN THE TAPING VALLEY.

Ponsee April 1868.

April.	THERMOMETERS.								WIND.					
	Maximum.	Minimum.	DRY BULB.			WET BULB.			7 A.M.		4 P.M.		9 P.M.	
			7 a.m.	4 p.m.	9 p.m.	7 a.m.	4 p.m.	9 p.m.	Lower.	Upper.	Lower.	Upper.	Lower.	Upper.
1	D 78· W 69·4	D 57·5 W 55·	59·	72·	61·	57·5	67·	59·	N E	S W	S W	S W	North	S W
2	D 81·2 W 70·5	D 73·2 W 66·	73·2	71·	62·5	66·	65·	59·6	N E	..	S	S W	N W	S W
3	D 84· W 73·	D 57· W 54·	66·	81·	61·	61·2	70·	58·5	S W	...	S W	..	N	..
4	D 86· W 73·8	D 57· W 54·	68·	81·	60·	65·	69·5	57·	N W	S W	S S W	S W	N	..
5	D 88·4 W 75·5	D 57· W 53·3	62·3	75·4	63·	57·5	69·5	60·5	E	S W	Calm	S W	N W	S W
6	D 80· W 71·	D 55·1 W 54·5	59·	68·5	60·5	58·	69·	58·	N E	S W	S W	S W	N W	N W
7	D 79·7 W 71·5	D 52·4 W 51·5	60·	74·	55·3	58·5	67·5	54·5	N N E	S W	S	S W	N	..
8	D 83·8 W 73·	D 52·7 W 51·	56·	81·	61·5	53·5	69·	60·	N E	S W	S W	S W	Calm	S W
9	D 90· W 80·	D 56· W 54·	64·	84·	63·	59·	74·	61·	N E	S W	S W	S W	N	S W
10	D 91· W 79·7	D 57·8 W 57·	67·	75·	66·	62·8	71·	64·	N E	S W	N E	S W	Calm	..
11	D 79· W 69·8	D 61· W 59·5	65·3	67·5	62·	63·	65·	60·	N E	S W	N E	S W	N	..
12	D 84·7 W 58·	D 77· W 57·5	63·	78·8	64·	60·8	73·	61·	N E	S W	S W	S W	N	..
13	D 76· W 69·8	D 59·5 W 58·5	61·	73·	61·	60·	66·	58·5	N E	S W	S W	S W	N	..
14	D 75·5 W 72·	D 57·5 W 56·4	62·	71·	66·	58·5	66·	61·	N E	S W	N E	S W	N	S W
15	D 73· W 68·8	D 56·4 W 54·	64·	66·4	58·	59·4	64·5	56·	N E	S W	S W	S W	N	S W
16	D 81· W 78·	D 53· W 53·4	61·3	73·	60·8	59·4	69·	60·	N E	..	S W	S W	Calm	..
17	D 86· W 78·7	D 58·4 W 57·8	69·	78·7	62·8	64·4	73·4	62·	N E	S W	S W	S W	N	S W
18	D 82·4 W 75·6	D 58· W 57·5	65·8	76·	63·	63·	72·4	61·	N E	S W	S W	S W	N	..
19	D 84·8 W 75·8	D 60· W 58·8	68·4	77·2	63·	64·4	71·3	62·	N E	S W	S W	S W	N	S W
20	D 85·5 W 72·5	D 61·3 W 60·	69·5	78·7	64·	65·4	72·5	62·8	N E	S W	S W	S W	Calm	..
21	D 88· W 79·	D 60·5 W 60·	68·	84·8	69·	64·5	74·8	66·	W	S W	S W	S W	N	..
22	D 82·5 W 79·5	D 60·3 W 59·5	73·8	82·5	67·	70·4	79·5	64·	Calm	S W	S W	S W	N	S W
23	D 87·8 W 87·8	D 56·2 W 59·	65·5	78·8	59·	64·	72·4	59·	N E	S W	N E	S W	N	..
24	D 84·3 W 77·	D 55· W 57·5	61·	78·	60·	60·5	75·	59·	N E	S W	S E	S W	N	..
25	D 80·4 W 72·3	D 56· W 51·5	64·5	67·4	58·	63·	62·	57·	N E	S W	N E	S W	N E	..
26	D 78·4 W 72·3	D 54·9 W 54·4	66·	67·	60·	76·3	64·5	59·	S W	S W	S W	S W	N	S W
27	D 82·3 W 71·4	D 55· W 54·5	62·	73·7	59·	69·5	73·	58·	N E	S W	S W	S W	N	S W
28	D 84·3 W 76·	D 57·3 W 56·5	65·	74·2	63·5	61·8	71·5	62·	N E	S W	S W	S W	N	S W
29	D 84·5 W 77·2	D 59· W 58·	63·5	74·5	64·	63·	71·	62·7	N E	S W	E	S W	N	S W
30	D 87·2 W 79·5	D 62·5 W 61·5	69·	80·	64·	66·8	72·	63·5	Calm	S W	S W	S W	N E	..

Ponsee, Sanda, Muangla, Nantin and Momien, May 1868.

May.	THERMOMETERS.								WIND.					
	Maximum.	Minimum.	Dry Bulb.			Wet Bulb.			7 A.M.		4 P.M.		9 P.M.	
			7 a.m.	4 p.m.	9 p.m.	7 a.m.	4 p.m.	9 p.m.	Lower.	Upper.	Lower.	Upper.	Lower.	Upper.
1	D 87·5 W 84·8	D 61·8 W 61·	67·	75·5	64·5	65·	71·	62·	N E	S W	S W	S W	N	0·
2	D 88·3 W 84·4	D 62·4 W 60·8	70·	86·5	64·5	67·	73·	64·	S W	S W	S W	S W	N	0·
3	D 85·8 W 81·5	D 62·5 W 56·3	67·3	86·7	66·	61·3	74·	63·	N E	0·	S W	0·	N	0·
4	D 84· W 81·	D 62·5 W 57·4	72·	85·5	64·	63·5	72·5	61·	N E	0·	S W	0·	N	0·
5	D 85·2 W 80·	D 62· W 57·	66·1	81·7	64·9	60·1	73·5	63·	E	0·	S W	9·	N	0·
6	D 84· W 79·	D 61·5 W 58·	68·	82·5	60·5	61·5	73·5	59·5	E	S W	S W	S W	N	0·
7	D 80·4 W 73·7	D 60·5 W 59·	64·5	80·	65·5	62·7	74·	64·	N W	S W	N W	S W	N W	S W
8	D 81·7 W 76·	D 55·5 W 55·	60·5	81·3	60·	60·	70·	5a·8	S W	S W	S W	S W	N	S W
9	D 89· W 76·8	D 59·5 W 57·5	65·3	64·	62·	61·4	63·	51·	N E	S W	S W	S W	N	S W.
	Sanda	Sanda	Sanda	Sanda	Sanda	Sanda	Sanda	Sanda	Sanda	Sanda	Sanda	Sanda	Sanda	Sanda
15	D 90·5 W 79·	D 59·5 W 57·5	69·	70·	69·	63·	70·	63·	... S W	... S W	... S W	N E S W	S W Calm	4·
	Muangla	Muangla	Muang.	Muang.	Muang.	Muang.	Muang.	Muang.	Muang.	Muang.	Muang.	Muang.	Muang.	Muang.
17	D 94· W 83·	D 63·5 W 57·3	68·9	..	71·3 72·5	... 60·4	.. ..	55·5 69·5	S W	S W	S W	0·	0·	0·
18	D 83· W 75·2	D 68·5 W 62·8	73·	70·5	68·	65·2	68·	64·	N E	S W	N E	S W	N E	S W
19	D 81·8 W 75·	D 64·5 W 63·8	67·2	77·5	71·	66·	70·	63·	N E	S W	S S W	S W	0·	S W
20	D 81·5 W 78·5	D 66·5 W 64·2	69·5	73·7	70·	66·6	69·5	66·5	Calm	S W	S W	S W	0·	0·
21	D 89·5 W 80·5	D 63·7 W 62·	67·5	82·5	71·	64·5	71·5	66·1	Calm	S W	S W	S W	Calm	0·
22	D 78· W 75·3	D 65·6 W 63·1	69·	74·	70·5	65·5	70·5	68·	Calm	S W	N W	S W	N	0·
	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin
23	D W	D 65·8 W 64·5	66·8	6·	73·	64·9	..	69·	Calm	0·	..	..	...	0·
24	D 83·2 W 66·7	D 63·5 W 61·8	67·	79·7	69·5	64·	71·7	65·6	Calm	4·	S W	S W	N	0·
25	D 88·7 W 78·7	D 64·5 W 63·	70·	81·5	73·	66·4	73·	61·2	S W	S W	S W	S W	S W	0·
26	D W	D 63· W 63·	64·8	..	..	62·	..	..	S W	0·	..	..	..	0·
	Momien	Momien	Momien	Momien	Momien	Momien	Momien	Momien	Momien	Momien	Momien	Momien	Momien	Momien
27	D 80· W 71·4	...	72·5	66·5	..	66·5	64·	..	..	...	S W	S W	S W	S W
28	D 87· W 76·4	D 61·5 W 60·	66·	79·5	66·4	64·	69·	63·5	Calm	0·	S E	S W	S W	0·
29	D 67· W 61·2	D 61·4 W 59·5	62·	61·5	58·5	61·5	57·	55·	S W	S W	S W	0·	S W	S W
30	D 76· W 71·	D 55·5 W 53·	58·7	74·	65·	57·	60·9	62·	Calm	0·	S W	S W	0·	0·
31	D 79· W 76·	D 59·7 W 58·2	61·5	out	64·4	60·	out	63·5	S W	S W	...	...	S W	S W

Momien, June, 1868.

June.	THERMOMETERS.								WIND.					
	Maximum.	Minimum.	Dry Bulb.			Wet Bulb.			7 A.M.		4 P.M.		9 P.M.	
			7 a.m.	4 p.m.	9 p.m.	7 a.m.	4 p.m.	9 p.m.	Lower.	Upper.	Lower.	Upper.	Lower.	Upper.
1	D W	D 55·3 W 54·	56·5	..	..	54·7	..	..	S W	S W	..	..	..	..
2	D 76· W 70·	D 51· W 51·4	52·4	73·	63·	52·4	63·6	60·5	Calm	0·	S W	0·	S W	0·
3	D 80·3 W 73·3	D 59·6 W 58·	62·2	76·5	69·	60·5	71·3	65·5	S W	0·	S W	N E	S W	S W
4	D 73·8 W 70·3	D 58· W 58·	62·	68·3	..	68·3	65·5	..	Calm	0·	S W	N N W	..	..
5	D 80·2 W 74·	..	..	73·5	65·4	..	68·	63·8	..	..	S W	N E	S W	0·
6	D 78· W 71·8	D 58·3 W 57·5	63·	72·5	63·	61·5	68·	61·	S W	0·	S W	S W	S W	0·
7	D 72· W 66·	D 61·3 W 60·	65·5	69·5	64·6	63·5	66·	64·	S W	S W	S W	S W	N E	S W
8	D 73· W 69·8	D 62·7 W 62·4	62·8	64·7	64·5	62·5	62·5	64·5	S W	0·	S W	S W	S W	S W
9	D 73·8 W 71·2	D 62·5 W 62·5	63·1	70·8	66·	63·1	68·	64·5	S W	S W	S W	S W	S W	S W
10	D 72· W 70·	D 63·5 W 63·	64·5	67·2	63·5	64·	66·	63·	S W	S W	S W	S W	S W	S W
11	D 70·8 W 69·	D 62·5 W 62·5	64·	69·3	65·	64·	68·	64·	S W	S W	S W	S W	S W	S W
12	D 71·4 W 69·5	D 63·5 W 63·	65·2	68·	65·5	64·5	66·7	64·8	S W	S W	S W	S W	S W	S W
13	D 70· W 68·	D 64· W 63·6	65·	68·	65·5	64·3	66·7	64·5	S W	S W	S W	S W	S W	S W
14	D 70· W 68·8	D 63·7 W 63·2	65·	67·2	65·	64·5	66·6	64·5	S W	S W	S W	S W	S W	S W
15	D 71·3 W 69·3	D 63·5 W 63·	65·5	67·4	65.7	65·2	66·	65·	S W	S W	S W	S W	S W	S W
16	D 71·3 W 69·2	D 64·7 W 64·3	65·	69·	65·5	64·8	68·	64·7	S W	S W	S W	S W	S W	S W
17	D 73·6 W 71·	D 64·5 W 63·5	64·8	70·	67·5	63·7	68·6	66·9	S W	S W	S W	S W	S W	S W
18	D 76· W 73·	D 65·6 W 65·	66·3	76·5	68·5	65·7	70·7	67·3	S W	S W	S W	S W	S W	S W
19	D 76·2 W 73·	D 66·3 W 65·5	68·	73·3	68·3	67·5	70·7	67·5	S W	S W	S W	S W	S W	S W
20	D 77·5 W 73·3	D 66· W 65·5	67·5	72·5	68·	66·8	69·7	67·	S W	S W	S W	S W	S W	S W
21	D 76· W 72·3	D 65·5· W 64·5	67·4	74·5	67·	66·	69·7	66·	S W	S W	S W	S W	S W	S W
22	D 77· W 73·3	D 65· W 64·3	68·	71·7	68·	66·5	71·	66·5	S W	S W	S W	S W	S W	S W
23	D 79· W 74·	D 65· W 64·	65·	76·5	68·5	64·	68·7	66·8	S W	S W	S W	S W	S W	S W
24	D 81· W 76·5	D 65· W 63·8	66·	75·	69·8	65·	72·5	68·	S W	S W	S W	S W	S W	S W
25	D 77·6 W 74·	D 67·5 W 66·3	69·	75·8	69·4	67·4	71·5	67·5	S W	S W	S W	S W	S W	S W
26	D 76·7 W 72·8	D 66·5 W 65·4	68·4	74·7	69·2	67·4	71·8	68·	S W	S W	S W	S W	S W	S W
27	D 78·7 W 74·7	D 66·5 W 65·5	67·5	74·7	69·5	66·5	70·2	68·	S W	S W	S W	S W	Calm	0·
28	D 75· W 72·3	D 66·4 W 65·5	67·9	72·	66·3	66·8	69·	65·5	S W	S W	S W	S W	S W	S W
29	D 75·4 W 72·	D 66· W 65·	66·	67·4	67·	65·	66·	65·5	S W	S W	S W	S W	S W	S W
30	D 72·3 W 69·2	D 61·5 W 61·	62·5	68·	66·5	61·	65·5	61·	S W	S W	S E	N E	S W	S W

Momien, Nantin, Muangla and Sanda, July 1868.

July.	THERMOMETERS.								WIND.					
	Maximum.	Minimum.	Dry Bulb.			Wet Bulb.			7 A.M.		2 P.M.		9 P.M.	
			7 a.m.	4 p.m.	9 p.m.	7 a.m.	4 p.m.	9 p.m.	Lower.	Upper.	Lower.	Upper.	Lower	Upper.
1	D 72· W 69·3	D 63· W 62·	64·6	69.5	66·5	64·	67·5	65·8	S W	S W	S W	S W	S W	S W
2	D 71·6 W 69·	D 65· W 64·4	65·6	69·	66·	64·9	67·5	66·5	S W	S W	S W	S W		
3	D 77· W 73·	D 64·2 W 64·	65·3	71·4	67·5	64·8	69·7	66·5	S W	S W	S W	S W	S W	S W
4	D 74·8 W 71·7	D 65·5 W 64·6	66·	71·1	68·	65·	69·5	66·7	S W	S W	S W	S W	S W	S W
5	D 75·6 W 72·	D 65·5 W 64·6	67·	70·5	67·	66·	68·2	61·6	S W	S W	S W	S W		
6	D 76·7 W 72·3	D 65· W 64·	62·5	74·1	67·5	61·1	70·7	62·	S W	S W	S W	S W	S W	S W
7	D 71·2 W 68·9	D 65· W 64·5	66·	67·5	65·5	65·5	66·	64·5	S W	S W	S W	S W		
8	D 70· W 68·	D 64·5 W 64·	65·5	66·5	65·5	64·8	64·9	63·5	S W	S W	S W	S W		
9	D 71·3 W 69·3	D 64· W 62·5	65·	68·5	65·5	63·5	66·9	64·	S W	S W	S W	S W		
10	D 71·8 W 69·8	D 64· W 63·5	65·	69·5	65·5	64·6	68·	64·8	..	..	S W	S W	Calm	Calm
11	D 71·8 W 69·3	D 65· W 64·	66·5	68·5	65·5	65·7	66·8	64·	..	..	S W	S W	Calm	Calm
12	D 74·9 W 74·9	D 64·3 W 63·5	65·6	70·5	66·5	65·	68·	64·8	..	S W	S W	S W	Calm	S W
13	D W	D 65·3 W 64·	65·5	..	..	64·3	..	..	S W	S W				
	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin	Nantin
14	D 74·4 W 71·8	..	..	71·8	69·7	..	70·	68·2	..	..	S W	S W	S W	S W
15	..	D 68·1 W 59·9	68·4	..	..	68·	..	..	S W	S W				

Between Nantin and Muangla all the thermometers with which the previous observations were made were stolen.

APPENDIX V.

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1875.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THEMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vaccus. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 2nd Jany. '75.	Akyab	73	77	66	68	7	9	64	58	..	55	82	129	..	..	..	N E	
	Kyouk-phyoo	73	75	70	72	3	3	88	64	..	...	84	138	..	..	..	NE & NW	
	Sandoway	73	78	65	70	8	8	63	60	..	49	81	138	..	..	..	E W	
	Rangoon	79	97	75	81	4	16	62	68	..	..	86	104	..	..	..	S W	
	Bassein	79	88	71	73	8	15	58	58	..	...	86	154	..	..	..	Not given	
	Henzada	72	85	68	74	4	11	68	62	..	...	85	140	..	..	..	N E	
	Prome	73	83	66	71	7	12	59	65	..	...	84	..	..	..	..	N E	
	Thayetmyo	74	83	67	72	7	11	56	83	..	81	85	140	..	..	..	N E	
	Toungoo	74	83	67	73	7	10	64	54	..	...	84	141	..	..	..	N E	
	Maulmain	71	87	73	75	8	13	56	66	..	..	89	136	..	..	..	N E	
	Tavoy	78	85	72	75	6	10	67	67	..	...	85	..	..	..	..	N E	
	Mergui	79	82	73	74	6	8	70	73	..	66	83	143	..	..	..	N W	
	Shwe-gyeen	75	78	75	72	1	6	86	72	..	66	83	130	..	..	..	N E	
Week ending 9th Jany. 1875	Akyab	73	75	66	66	7	9	63	57	..	50	80	129	..	..	..	N E	
	Kyouk-phyoo	74	77	70	74	4	3	82	67	..	..	81	138	..	..	..	N E N W	
	Sandoway	72	76	67	68	5	8	69	62	..	52	78	132	..	..	5	S W	
	Rangoon	79	82	70	69	9	13	55	64	..	84	67	97	..	..	..	..	
	Bassein	78	80	71	72	7	8	65	62	..	..	84	153	..	..	..	Not given	
	Henzada	73	80	68	72	5	8	71	65	..	...	80	93	..	..	8	NE & NW	
	Prome	71	80	67	69	4	11	66	64	..	...	81	..	..	..	..	N E	
	Thayetmyo	74	80	67	71	7	9	65	60	..	64	85	131	..	..	69	do.	
	Toungoo	75	82	69	70	6	12	62	58	..	...	97	142	..	..	..	N E	
	Maulmain	79	84	70	71	9	13	54	64	..	...	86	130	..	..	..	N E	
	Tavoy	76	82	68	71	8	11	60	63	..	...	82	..	..	..	..	N E	
	Mergui	78	83	69	73	9	10	66	68	..	54	85	145	..	..	..	N E	
	Shwe-gyeen	72	73	76	71	4	2	85	71	..	66	82	130	..	..	..	N W	
Week ending 16th Jany. '75	Akyab	70	75	64	65	6	10	62	56	..	48	80	131	..	...	..	E N E	
	Kyouk-phyoo	74	77	71	74	3	3	79	64	..	..	81	138	..	..	..	NE & NW	
	Sandoway	69	75	64	66	5	9	63	56	..	48	78	137	..	..	..	S W	
	Rangoon	77	86	67	68	10	18	45	59	..	84	89	106	..	..	..	S E	
	Bassein	77	80	72	70	5	10	59	56	..	...	84	153	..	..	..	Not given	
	Henzada	69	83	64	70	5	13	60	58	..	...	83	117	..	..	..	NE & NW	
	Prome	69	81	63	65	8	16	49	59	..	..	82	..	..	..	..	N E	
	Thayetmyo	74	78	66	70	8	8	68	56	..	58	82	136	..	..	..	do.	
	Toungoo	73	82	64	68	9	14	52	47	..	...	86	140	..	..	..	N E	
	Maulmain	78	87	69	71	9	16	49	61	..	...	89	133	..	..	..	E & S W	
	Tavoy	74	85	69	73	5	12	64	60	..	...	85	..	..	..	..	NE & NW	
	Mergui	80	85	73	76	7	9	70	69	..	65	86	147	..	..	..	NE & NW	
	Shwe-gyeen	72	74	72	73	1	1	82	72	..	66	81	130	..	..	..	S W	
Week ending 23rd Jany. '75	Akyab	71	74	66	65	5	9	67	58	..	...	80	134	..	..	..	EN & NW	
	Kyouk-phyoo	76	79	70	75	6	4	75	65	..	51	84	131	..	..	..	E W	
	Sandoway	70	74	63	64	7	10	59	59	..	51	77	136	..	..	..	S E	
	Rangoon	77	85	70	63	7	7	69	59	..	82	88	107	..	..	..	Not given	
	Bassein	77	79	68	68	9	11	55	56	..	...	84	154	..	..	..	NE & NW	
	Henzada	71	82	65	70	6	12	60	59	..	...	82	111	..	..	..	NE & SE	
	Prome	69	80	64	67	5	13	59	61	..	...	81	..	..	..	..	N E	
	Thayetmyo	72	81	64	70	8	11	59	52	..	52	82	141	..	..	..	N E	
	Toungoo	72	80	65	68	7	12	52	50	..	...	98	142	..	..	..	E N E	
	Maulmain	79	86	70	70	9	16	49	62	..	...	88	132	..	..	..	NE & NW	
	Tavoy	73	82	68	71	5	11	65	61	..	...	82	..	..	..	..	NE & NW	
	Mergui	78	83	71	73	7	10	67	65	..	61	85	148	..	..	..	S E	
	Shwe-gyeen	70	72	71	71	1	1	82	71	..	65	78	128	..	..	..	...	
Week ending 30th Jany. '75.	Akyab	71	75	64	65	7	10	60	57	..	...	81	137	..	..	..	N E	
	Kyouk-phyoo	76	79	72	75	4	4	82	62	..	...	86	128	..	..	..	N E & W	
	Sandoway	70	77	65	67	5	10	65	58	..	48	79	140	..	..	..	E & W	
	Rangoon	80	85	72	73	8	12	60	64	..	84	90	102	..	..	..	N W	
	Bassein	78	82	69	72	9	10	56	68	..	...	86	156	..	..	..	..	
	Henzada	73	86	68	73	5	13	61	64	..	..	86	113	..	..	..	N E N W	
	Prome	74	85	69	68	5	17	54	62	..	...	85	..	..	..	..	N E S W	
	Thayetmyo	74	82	64	70	10	12	55	52	..	49	83	144	..	..	..	S W	
	Toungoo	74	85	68	74	6	11	59	56	..	...	94	142	..	..	..	S S E	
	Maulmain	80	88	71	74	9	14	52	66	..	..	91	133	..	..	..	N E	
	Tavoy	75	84	70	74	5	10	68	65	..	...	84	..	..	..	..	do.	
	Mergui	81	84	72	74	9	10	74	68	..	66	86	150	..	..	10	N E	
	Shwe-gyeen	71	72	72	71	1	1	81	71	..	65	71	130	..	..	..	Variable	
Week ending 6th Feby. 1875.	Akyab	73	77	65	67	8	10	60	57	..	..	80	138	..	..	..	N W	
	Kyouk-phyoo	76	80	70	76	6	4	76	64	..	..	87	145	..	..	..	NE & NW	
	Sandoway	71	80	64	68	7	12	58	59	..	47	87	139	..	..	..	E W	
	Rangoon	81	92	72	79	9	13	58	64	..	85	94	113	..	..	..	S E	
	Bassein	80	78	71	71	9	7	56	61	..	..	88	156	..	..	..	Not given	
	Henzada	75	87	69	74	6	13	60	65	..	..	87	117	..	..	..	NE & NW	
	Prome	76	88	67	71	9	17	49	63	..	..	88	..	..	..	..	N E	
	Thayetmyo	75	83	64	70	11	13	53	53	..	47	83	145	..	..	..	S W S E	
	Toungoo	77	86	68	69	9	17	49	54	..	..	94	146	..	..	..	S W	
	Maulmain	82	93	71	75	11	18	44	67	..	..	94	134	..	..	..	SE & NW	
	Tavoy	76	86	70	75	6	11	64	65	..	..	86	..	..	..	..	NE & NW	
	Mergui	81	86	73	76	8	10	70	67	..	64	88	156	..	..	..	do.	
	Shwe-gyeen	71	71	71	71	1	1	81	71	..	65	70	129	..	..	..	do.	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1875—Continued.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THERMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 13th Feby. 1875	Akyab	77	81	68	70	9	11	58	60	..	....	85	140	..	..	..	N W	
	Kyouk-phyoo	..	..	..	....	....	..	..	....	..	..	..	..	....	....	..	. .	
	Sandoway	75	80	67	71	8	9	63	60	..	50	84	141	..	..	..	E W	
	Rangoon	81	93	70	72	11	21	42	62	..	84	96	112	..	..	..	S E N E	
	Bassein	81	84	71	71	10	13	52	62	..	..	91	157	..	....	..	. .	
	Henzada	72	90	67	73	5	17	56	61	..	..	90	120	..	..	..	N E	
	Prome	76	90	67	70	9	20	44	63	..	....	91	..	..	....	..	N E S E	
	Thayetmyo	79	85	66	70	13	15	45	55	..	43	86	150	....	..	..	S E	
	Toungoo	..	..	..	....	..	..	..	..	..	....	..	..	....	....	..	..	
	Maulmain	82	92	74	76	8	16	52	67	..	..	94	133	..	....	..	N E S W	
	Tavoy	77	86	74	77	3	9	74	69	..	....	87	....	....	....	½	N E N W	
	Mergui	83	87	77	79	6	8	74	72	..	70	88	150	....	....	4	N E S W	
	Shwe-gyeen	71	71	71	72	..	1	81	..	..	...	71	130	..	....	..	S E	
Week ending 20th Feby. 1875	Akyab	79	81	67	69	12	12	51	58	..	....	86	143	....	..	..	N W	
	Kyouk-phyoo	..	..	..	....	..	..	..	..	..	..	....	..	....	..	..	. .	
	Sandoway	75	81	68	72	7	9	65	62	..	52	84	140	....	....	..	E and W	
	Rangoon	81	94	73	74	8	20	49	61	..	85	97	112	..	....	..	N W	
	Bassein	82	86	75	74	7	12	56	65	..	..	91	158	..	..	..	. .	
	Henzada	74	91	69	72	5	19	52	63	..	..	91	121	..	....	..	N E	
	Prome	77	92	68	70	9	22	42	65	..	..	93	..	..	..	..	do.	
	Thayetmyo	81	90	66	72	15	18	43	55	..	50	95	152	..	....	..	S E	
	Toungoo	..	..	..	....	..	..	..	..	..	..	....	....	..	....	..	. .	
	Maulmain	83	90	75	78	8	12	56	71	..	..	95	136	....	..	..	N E S W	
	Tavoy	80	87	76	78	4	10	72	74	..	..	87	....	..	....	..	S E	
	Mergui	83	87	76	80	7	7	73	72	..	72	90	148	....	....	..	N E N W	
	Shwe-gyeen	71	72	71	71	....	1	81	..	..	..	71	130	..	..	..	S W	
Week ending 27th Feby. 1875	Akyab	81	83	69	72	12	11	54	62	..	..	88	146	....	..	..	W and NW	
	Kyouk-phyoo	76	80	73	77	3	3	81	67	..	..	83	131	....	..	..	N E and W	
	Sandoway	74	84	67	72	7	12	58	61	..	50	85	143	....	..	..	E W	
	Rangoon	83	97	72	73	11	24	39	63	..	86	100	114	....	..	..	N E	
	Bassein	84	86	73	69	11	17	50	66	..	..	93	158	....	..	..	Not given	
	Henzada	72	93	67	72	5	21	49	61	..	..	93	122	....	..	..	N E	
	Prome	79	95	68	71	11	24	38	63	..	..	96	..	....	..	..	N E	
	Thayetmyo	81	90	66	71	5	19	43	55	..	50	101	152	....	..	..	S E	
	Toungoo	..	..	..	....	..	..	..	..	..	..	..	..	..	..	..	..	
	Maulmain	83	92	75	78	8	12	53	71	..	....	96	140	....	..	..	N E & E W	
	Tavoy	81	89	77	79	4	10	72	73	..	..	89	....	..	..	..	N E & N W	
	Mergui	85	90	73	80	12	10	74	73	..	70	91	153	....	..	..	S W & N W	
	Shwe-gyeen	72	71	72	72	1	1	81	..	..	..	72	129	..	..	..	N W	
Week ending 6th March 1875	Akyab	77	82	67	70	10	12	54	60	..	..	88	147	..	..	..	E	
	Kyouk-phyoo	88	82	76	79	12	3	77	66	..	..	89	148	..	..	..	N E & N W	
	Sandoway	75	83	64	70	11	13	51	59	....	49	85	143	..	..	..	E W	
	Rangoon	85	94	72	73	13	21	41	63	..	87	100	113	..	..	..	N W	
	Bassein	84	88	70	66	14	22	36	64	..	..	94	160	..	..	..	Not given	
	Henzada	74	94	67	71	7	23	44	63	..	..	94	122	..	..	..	N E	
	Prome	80	94	67	69	13	25	34	64	..	..	97	..	..	..	..	N E	
	Thayetmyo	81	89	67	72	14	17	44	55	..	44	102	152	..	..	..	S W	
	Toungoo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Maulmain	85	91	..	77	9	14	52	69	..	..	97	138	..	..	..	N E & S W	
	Tavoy	80	89	..	78	5	11	68	71	..	..	90	..	..	..	..	N E & N W	
	Mergui	85	90	..	79	7	11	72	73	..	60	93	152	..	..	..	Not given	
	Shwe-gyeen	74	81	..	73	2	8	75	..	..	..	90	131	..	..	..	N E & S W	
Week ending 13th March-75	Akyab	80	80	74	74	6	6	74	70	....	..	85	131	..	..	..	Not given	
	Kyouk-phyoo	81	85	79	83	2	2	87	66	..	..	88	147	..	..	..	N E & N W	
	Sandoway	79	83	70	74	9	9	62	67	..	56	85	143	..	..	..	E W	
	Rangoon	83	92	73	75	10	15	53	65	..	37	97	108	..	..	..	N E	
	Bassein	84	85	76	71	8	14	54	68	..	..	92	162	..	..	..	Not given	
	Henzada	76	91	71	73	5	18	55	67	..	..	91	114	..	..	..	N E	
	Prome	85	95	75	87	10	8	66	66	..	..	97	..	..	..	..	N E N	
	Thayetmyo	84	90	72	73	12	17	44	55	..	40	102	152	..	..	..	N W	
	Toungoo	..	..	..	....	..	..	..	..	..	..	..	....	..	..	..	..	
	Maulmain	85	90	76	75	9	15	52	70	..	..	94	146	..	..	..	N E & S W	
	Tavoy	79	87	73	74	6	13	61	66	..	..	88	..	..	..	..	N E & N W	
	Mergui	84	87	77	77	7	10	72	71	..	67	89	150	..	..	..	N W & N E	
	Shwe-gyeen	73	82	73	73	1	9	73	..	..	..	91	130	..	..	..	S W	
Week ending 20th March-75	Akyab	82	83	76	77	6	6	75	71	..	..	88	147	..	..	..	Not given	
	Kyouk-phyoo	83	87	80	84	3	3	81	68	..	..	90	153	..	..	..	N W	
	Sandoway	81	85	73	76	8	9	74	72	..	59	87	144	..	..	..	N W	
	Rangoon	83	92	76	80	7	12	64	69	..	89	97	113	..	..	..	N W	
	Bassein	85	86	75	74	10	12	58	71	..	..	93	162	..	..	..	Not given	
	Henzada	78	95	73	77	5	18	57	69	..	..	95	115	..	..	..	N E & N W	
	Prome	90	95	75	84	15	11	51	75	..	....	97	..	..	..	..	N E N	
	Thayetmyo	88	98	75	75	13	23	44	69	..	66	103	156	..	..	..	S E	
	Toungoo	..	..	..	..	..	..	..	..	..	..	..	....	..	..	..	..	
	Maulmain	86	89	77	77	9	12	58	73	..	....	94	145	..	..	..	S W	
	Tavoy	82	88	76	79	6	9	70	74	..	..	89	..	..	..	..	N W	
	Mergui	84	87	78	80	6	7	74	73	..	72	88	150	..	..	1	S E N W	
	Shwe-gyeen	71	81	72	71	1	10	72	..	..	..	91	130	..	..	..	N E	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1875—Continued.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THEMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 27th March '75	Akyab	84	84	76	76	8	8	65	70	..	..	89	147	..	...	..	Not given	
	Kyouk-phyoo	82	85	77	80	5	5	75	68	..	..	89	150	..	...	..	NE N W	
	Sandoway	81	85	72	77	9	8	62	52	..	62	87	145	..	...	..	N W	
	Rangoon	84	93	76	79	8	14	59	70	..	87	99	114	..	...	..	N W	
	Bassein	85	87	75	76	10	11	56	69	..	..	93	165	..	..	..	Not given	
	Henzada	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Prome	90	99	77	80	13	19	43	80	..	..	100	..	...	...	..	N N E	
	Thayetmyo	88	97	75	73	13	24	44	69	..	64	102	158	...	...	..	S E	
	Toungoo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Maulmain	85	92	73	77	7	15	54	73	..	..	97	149	..	..	..	S W	
	Tavoy	82	89	77	79	5	10	70	73	..	..	90	..	..	..	..	SW & NE	
	Mergui	87	87	78	79	9	8	74	74	..	70	92	153	..	...	..	SE & NW	
	Shwe-gyeen	73	81	72	71	1	10	71	..	..	..	91	130	..	...	..	N E	
Week ending 3rd April '75.	Akyab	85	85	78	76	7	9	68	73	..	..	91	151	..	...	..	Not given	
	Kyouk-phyoo	83	86	80	83	3	3	79	68	..	..	89	151	..	...	..	NE & NW	
	Sandoway	83	85	75	78	8	7	65	75	..	63	88	147	..	...	..	NE & W	
	Rangoon	86	90	77	79	9	11	62	70	..	90	98	110	..	..	..	N W	
	Bassein	86	88	76	76	10	12	55	72	..	..	94	165	..	..	..	Not given	
	Henzada	81	94	75	79	6	15	69	73	..	..	94	116	..	...	..	N E	
	Prome	83	98	72	81	11	17	59	76	..	..	99	..	..	...	..	N N E	
	Thayetmyo	89	96	76	77	13	19	45	74	..	58	102	151	..	...	..	S E	
	Toungoo	91	93	76	75	15	23	38	72	..	..	104	151	..	...	..	Not given	
	Maulmain	85	92	77	78	8	14	55	75	..	..	93	150	..	...	3	S W	
	Tavoy	83	89	76	78	7	11	65	75	..	..	90	..	..	...	..	NE & NW	
	Mergui	87	89	78	79	9	10	73	74	..	94	92	154	..	2	..	SE & NW	
	Shwe-gyeen	71	81	72	72	1	9	71	..	..	..	91	130	..	...	..	N W	
Week ending 10th April '75	Akyab	88	87	80	80	8	7	71	74	..	..	91	151	..	..	..	Not given	
	Kyouk-phyoo	85	88	83	82	2	6	79	69	..	..	92	151	..	...	..	NE & NW	
	Sandoway	86	87	76	77	10	10	61	77	..	65	90	149	..	...	..	NW by W	
	Rangoon	86	95	78	81	8	14	60	73	..	90	100	117	..	...	..	NE & NW	
	Bassein	88	88	77	77	11	11	54	74	..	..	96	166	..	...	..	Not given	
	Henzada	83	96	77	80	6	16	59	73	..	..	97	123	..	...	..	N E	
	Prome	79	94	72	76	7	18	54	77	..	..	99	..	..	...	..	N N E	
	Thayetmyo	90	100	76	75	14	25	44	75	..	52	105	154	..	..	..	S E	
	Toungoo	92	99	78	76	14	23	41	72	..	..	..	153	...	..	..	Not given	
	Maulmain	87	93	78	79	9	14	53	77	..	..	97	150	..	..	..	S W	
	Tavoy	85	90	78	80	7	10	67	77	..	..	90	..	..	..	..	N W	
	Mergui	88	88	80	80	8	8	76	76	..	75	92	150	..	..	..	SE & NW	
	Shwe-gyeen	71	81	71	71	1	10	71	..	..	..	91	150	...	..	..	N E	
Week ending 17th April '75	Akyab	87	86	80	80	7	6	74	76	..	..	92	151	...	..	..	Not given	
	Kyouk-phyoo	86	89	83	85	3	4	79	71	..	..	92	145	.	..	..	NE & NW	
	Sandoway	84	87	75	78	9	9	61	75	..	66	90	149	..	..	..	N W W	
	Rangoon	90	91	78	79	12	12	56	74	..	89	99	117	..	..	..	NE & NW	
	Bassein	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Henzada	84	97	77	80	7	17	56	73	..	..	..	125	..	..	..	S W	
	Prome	83	99	74	82	9	17	54	79	..	..	97	..	..	..	..	N N E	
	Thayetmyo	91	101	75	77	16	24	44	71	..	..	100	..	...	..	..	S W	
	Toungoo	91	100	77	76	14	24	39	73	..	58	106	155	...	..	..	Not given	
	Maulmain	88	91	78	80	10	12	55	77	..	..	103	152	..	..	..	S W	
	Tavoy	84	89	78	80	6	9	70	75	..	..	96	152	...	..	..	NW & W	
	Mergui	84	82	80	78	4	4	76	73	..	..	90	..	...	..	..	NE & NW	
	Shwe-gyeen	71	81	71	72	1	9	71	..	..	74	91	153	...	..	6	S W	
Week ending 24th April '75	Akyab	82	84	77	78	5	6	77	74	..	..	88	141	...	..	..	Not given	
	Kyouk-phyoo	83	87	79	83	4	4	79	67	..	..	89	129	...	4	1	NE & NW	
	Sandoway	83	84	76	76	7	8	68	76	..	69	88	132	...	2	5	SE & NW	
	Rangoon	88	88	78	77	10	11	60	75	..	90	95	107	..	4	2	NE & NW	
	Bassein	89	89	76	76	23	13	51	74	..	..	96	166	...	2	6	Not given	
	Henzada	83	90	77	78	6	12	65	72	..	..	90	109	...	3	1	N E	
	Prome	80	88	71	77	9	11	67	76	..	..	91	..	..	2	..	N N E	
	Thayetmyo	85	92	74	74	11	18	58	71	..	54	90	139	...	3	4	N W	
	Toungoo	88	90	77	75	11	15	53	72	..	..	98	152	...	5	6	Not given	
	Maulmain	89	91	78	79	11	12	55	76	..	..	95	145	...	2	2½	S W	
	Tavoy	82	86	77	79	5	7	75	74	..	..	87	..	..	6	4	S W	
	Mergui	88	85	80	81	8	7	76	75	..	73	92	150	..	3	..	NE & NW	
	Shwe-gyeen	72	80	71	71	1	9	71	..	..	..	90	130	...	1	8½	N E	
Week ending 1st May 1875.	Akyab	82	82	78	77	4	5	81	72	..	..	87	151	...	7	½	Not given	
	Kyouk-phyoo	84	87	81	85	3	2	82	70	..	..	89	143	...	4	8	SE & NE	
	Sandoway	85	84	77	77	8	7	67	77	..	71	88	146	...	..	5	S W	
	Rangoon	85	89	79	79	6	10	62	74	..	86	94	111	..	..	½	NE & NW	
	Bassein	88	91	78	80	10	11	58	74	..	..	95	168	...	..	..	Not given	
	Henzada	84	92	79	79	5	13	66	75	..	..	92	116	..	..	..	N E	
	Prome	80	89	75	79	5	10	67	77	..	..	94	..	..	..	..	Not given	
	Thayetmyo	84	83	76	74	8	9	66	72	..	58	93	144	...	1	½	S W	
	Toungoo	87	92	78	77	9	15	56	73	..	..	95	147	...	1	1	Not given	
	Maulmain	82	86	77	78	5	8	69	74	..	..	89	143	...	3	1	S W	
	Tavoy	80	84	76	78	4	6	79	74	..	..	84	..	..	2	2¾	Variable	
	Mergui	84	82	79	78	5	4	76	74	..	75	86	147	...	3	..	NE & S W	
	Shwe-gyeen	71	81	71	71	1	10	71	..	..	..	91	130	...	..	..	S E	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1875—Continued.

	STATIONS.	Hygrometer in Shade. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	Minimum Thermometers. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	Maximum Thermometers. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 8th May 1875.	Akyab	85	86	77	79	8	7	70	74	..	..	80	147	..	1	2	..	
	Kyouk-phyoo	83	87	80	85	3	2	89	67	..	..	90	134	..	2	6	N E S W	
	Sandoway	85	86	77	77	8	9	66	78	..	71	89	148	..	..	7	S W	
	Rangoon	82	84	76	77	6	7	72	75	..	86	90	98	..	3	1	S W N W	
	Bassein	85	86	78	78	7	8	69	75	..	..	91	170	..	..	..	..	
	Henzada	83	86	78	78	5	8	74	76	..	..	86	101	..	..	2	N E	
	Prome	83	90	77	79	6	11	65	76	..	..	90	..	..	..	½	S W	
	Thayetmyo	86	91	74	78	9	13	57	75	..	69	97	146	..	1	..	S W	
	Toungoo	90	91	80	78	10	13	38	73	..	..	94	148	..	2	4	..	
	Maulmain	82	82	77	77	5	5	76	74	..	..	88	143	..	3	3	S W	
	Tavoy	77	80	76	76	1	4	89	74	..	..	80	..	..	5	3½	Variable	
	Mergui	89	79	77	76	2	3	74	73	..	77	83	141	..	9	3½	S W	
	Shwe-gyeen	81	81	71	71	..	10	71	..	..	..	92	131	..	3	6	S W	
Week ending 15th May 1875	Akyab	80	83	77	78	3	5	83	74	..	..	86	140	..	7	¾	Not given	
	Kyouk-phyoo	82	85	78	81	4	4	81	67	..	..	89	137	..	5	¾	S W	
	Sandoway	81	84	76	77	5	7	75	76	..	72	85	146	..	..	9	E S W	
	Rangoon	83	84	79	77	4	7	76	74	..	83	89	98	..	5	¾	N W	
	Bassein	84	82	77	78	7	4	76	74	..	..	88	170	..	1	¾	Not given	
	Henzada	82	83	78	78	4	5	81	74	..	..	83	89	..	4	1	N E	
	Prome	83	90	78	80	5	10	67	79	..	..	90	..	..	..	1	S W	
	Thayetmyo	84	85	79	78	5	7	72	77	..	63	92	140	..	..	½	S W	
	Toungoo	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Maulmain	82	83	78	78	4	5	76	74	..	..	85	142	..	4	6½	S W	
	Tavoy	82	83	78	78	4	5	81	74	..	..	82	..	..	2	1½	S W	
	Mergui	85	86	80	79	5	7	76	74	..	76	88	149	..	1	..	S W	
	Shwe-gyeen	71	82	71	71	1	11	71	..	..	..	91	131	..	2	2	S W	
Week ending 22nd May -75.	Akyab	87	88	80	80	7	8	71	74	..	..	90	151	..	..	97	Not given	
	Kyouk-phyoo	86	88	85	86	1	2	85	74	..	..	92	154	..	..	2	N E & W	
	Sandoway	83	84	77	78	6	6	72	77	..	71	87	148	..	1	6	E S W	
	Rangoon	78	77	76	75	2	2	84	73	..	79	86	88	..	6	5	N W	
	Bassein	84	80	78	77	6	3	77	75	..	..	88	169	..	2	2	Not given	
	Henzada	83	83	78	78	5	5	79	75	..	..	83	93	..	1	9	SW & NE	
	Prome	83	87	77	79	6	8	72	77	..	..	90	..	..	..	¼	S W	
	Thayetmyo	84	89	83	79	1	10	75	74	..	63	97	149	..	2	½	SW & SE	
	Toungoo	82	84	77	77	5	7	75	75	..	..	89	147	..	..	2	Not given	
	Maulmain	83	83	78	77	5	6	73	74	..	..	88	136	..	2	5½	S W	
	Tavoy	84	84	78	78	6	6	75	74	..	..	84	..	..	1	1	SW & NE	
	Mergui	84	86	80	83	4	3	82	74	..	74	91	151	..	..	9	N W	
	Shwe-gyeen	72	80	71	71	1	9	72	..	..	..	91	130	..	3	8	S W	
Week ending 29th May 1875	Akyab	87	85	81	80	6	5	78	76	..	..	89	152	..	..	8·03	Not given	
	Kyouk-phyoo	80	84	77	80	3	4	85	70	..	..	85	150	..	1	7	NE & SW	
	Sandoway	82	82	77	77	5	5	77	76	..	72	85	143	..	6	3	EW & SE	
	Rangoon	83	82	78	77	5	5	79	75	..	81	86	96	..	2	..	N W	
	Bassein	81	84	78	78	3	6	82	75	..	..	86	163	..	4	..	Not given	
	Henzada	81	82	78	78	3	4	85	75	..	..	82	91	..	3	5	S E	
	Prome	81	82	78	78	3	4	85	75	..	..	87	..	..	1	..	S E	
	Thayetmyo	85	89	79	77	6	12	65	74	..	58	97	146	..	..	..	S E	
	Toungoo	83	82	78	79	5	3	83	75	..	..	86	142	..	1	1¼	..	
	Maulmain	82	84	78	78	4	6	74	73	..	..	89	145	..	5	4½	S W	
	Tavoy	82	84	78	79	4	5	81	75	..	..	84	..	..	1	7½	SW & SE	
	Mergui	84	84	79	79	5	5	76	74	..	77	87	142	..	3	½	NE & SW	
	Shwe-gyeen	72	81	72	71	1	10	71	..	..	..	92	130	..	7	7	S W	
Week ending 6th June 1875.	Akyab	86	84	81	79	5	5	79	78	..	..	92	151	..	2	3	Not given	
	Kyouk-phyoo	83	87	77	81	6	6	78	72	..	..	91	148	..	5	8	SW & SE	
	Sandoway	83	83	77	78	6	5	75	77	..	73	86	147	..	3	9	S W	
	Rangoon	79	80	76	77	3	3	87	75	..	80	83	92	..	6	9	N W	
	Bassein	83	80	70	78	3	2	87	75	..	..	87	168	..	4	½	Not given	
	Henzada	83	82	79	79	4	3	85	76	..	..	82	95	..	1	6	S W	
	Prome	83	83	78	78	5	5	79	76	..	..	87	..	..	1	¼	S W	
	Thayetmyo	84	88	76	79	8	9	62	73	..	56	96	149	..	1	½	S E	
	Toungoo	82	82	70	80	2	2	91	76	..	..	88	127	..	3	57	..	
	Maulmain	81	83	77	78	4	5	75	74	..	..	86	138	..	6	2½	S W & S	
	Tavoy	77	80	76	77	1	3	91	74	..	..	80	..	..	13	6¼	S W	
	Mergui	78	79	76	77	2	2	75	74	..	71	82	127	..	11	¼	NE & SW	
	Shwe-gyeen	71	81	71	71	1	10	71	..	..	..	91	130	..	2	8	S W	
Week ending 12th June 1875	Akyab	82	83	79	79	3	4	85	76	..	..	86	129	..	8	9	Not given	
	Kyouk-phyoo	75	78	72	75	3	3	81	69	..	..	83	141	..	10	..	SE & SW	
	Sandoway	83	82	78	78	5	4	78	77	..	73	85	145	..	4	1	SW & SE	
	Rangoon	83	84	79	79	4	5	78	76	..	86	88	100	..	1	7	N W	
	Bassein	83	81	79	78	4	3	86	75	..	..	87	168	..	2	..	Not given	
	Henzada	83	81	79	79	4	2	87	76	..	..	81	84	..	2	..	S W	
	Prome	83	81	79	77	4	4	83	75	..	..	89	..	..	3	¼	S W	
	Thayetmyo	81	87	75	80	6	7	70	73	..	58	96	155	..	3	¼	S E	
	Toungoo	82	83	78	79	4	4	83	75	..	..	86	123	..	4	..	Not given	
	Maulmain	83	85	78	79	5	6	77	75	..	..	84	145	..	3	1¼	S W	
	Tavoy	81	85	78	79	3	6	81	75	..	..	85	..	..	1	7	S W	
	Mergui	84	85	80	81	4	4	78	75	..	76	89	146	..	..	¾	NE & SW	
	Shwe-gyeen	72	82	71	72	1	10	71	..	..	..	92	130	..	7	7	S W	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1875.—Continued.

	STATIONS.	Hygrometer in shade. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	Minimum Themometers. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	Maximum Thermometers. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 19th June '75.	Akyab	82	82	80	80	2	2	91	76	..	...	86	138	..	12	4	Not given	
	Kyouk-phyoo	77	80	74	77	3	3	83	65	..	..	86	141	..	15	7	SE & SW	
	Sandoway	80	80	77	78	3	2	86	76	..	73	83	136	..	12	..	E S E	
	Rangoon	81	79	78	76	3	3	87	74	..	80	85	85	..	...	24	N W	
	Bassein	81	80	78	77	3	3	86	75	..	...	87	165	..	3	¾	Not given	
	Henzada	83	82	79	77	4	5	81	76	..	...	82	90	..	2	3	S W	
	Prome	82	82	78	78	4	4	83	75	..	...	86	..	..	...	¾	do.	
	Thayetmyo	83	85	78	79	5	6	76	76	..	59	89	138	..	...	¾	do.	
	Toungoo	82	84	78	81	4	3	85	75	..	..	85	126	..	4	¾	Not given	
	Maulmain	79	82	76	78	3	4	85	73	..	...	84	131	..	14	2¼	S W	
	Tavoy	79	80	77	77	2	3	89	74	..	..	80	...	..	11	2¼	do.	
	Mergui	82	80	77	78	5	2	76	76	..	75	85	144	..	10	½	NW & SW	
	Shwe-gyeen	71	81	71	72	1	9	71	..	..	..	91	131	..	7	4	S W	
Week ending 26th June 1875	Akyab	80	80	79	79	1	1	96	75	..	..	84	122	..	16	9	Not given	
	Kyouk-phyoo	72	75	68	72	4	3	81	64	..	..	82	137	..	30	5	S W	
	Sandoway	80	80	78	78	2	2	88	77	..	74	82	132	..	26	9	E S W	
	Rangoon	82	80	79	77	3	3	86	75	..	81	85	87	..	1	·27	N E	
	Bassein	80	82	81	77	1	5	84	76	..	...	87	161	..	5	¾	Not given	
	Henzada	82	82	79	77	3	5	83	74	..	...	82	91	..	5	3	S W	
	Prome	82	83	77	79	5	4	81	76	..	...	85	..	..	1	¾	do.	
	Thayetmyo	83	83	80	79	3	4	79	76	..	58	88	131	..	1	1¾	do.	
	Toungoo	73	83	77	79	1	4	89	75	..	...	85	129	..	5	¼	Not given	
	Maulmain	80	80	77	77	3	3	85	73	..	...	83	125	..	22	¾	S W	
	Tavoy	77	79	75	77	2	2	91	73	..	..	79	..	..	14	3¼	Variable	
	Mergui	80	79	78	75	2	4	75	74	..	74	83	120	..	9	...	NW & SW	
	Shwe-gyeen	71	81	71	71	1	10	71	...	..	..	91	130	..	13	4	S W	
Week ending 3rd July 1875.	Akyab	84	81	80	79	4	2	87	76	..	....	85	136	..	9	7	Not given	
	Kyouk-phyoo	76	81	75	76	..	..	79	63	..	...	84	137	..	11	7	SW & SE	
	Sandoway	80	80	77	77	..	..	87	75	..	73	82	132	..	19	1	ESE & SW	
	Rangoon	80	80	77	76	..	..	85	73	..	78	83	96	..	4	·21	S E	
	Bassein	81	82	78	79	..	..	88	75	..	..	86	159	..	13	·09	Not given	
	Henzada	82	80	79	78	3	2	89	75	..	..	80	86	..	4	8	S W	
	Prome	81	83	78	76	3	7	79	75	..	..	84	..	..	1	¾	do.	
	Thayetmyo	82	83	79	79	3	4	85	73	..	56	90	131	..	4	21	do.	
	Toungoo	80	83	77	76	3	7	78	77	..	..	85	131	..	2	½	Not given	
	Maulmain	79	78	77	76	..	..	92	73	..	..	81	117	..	13	4¼	S W	
	Tavoy	77	78	76	77	1	1	95	73	..	...	79	...	..	16	6¾	SW & NE	
	Mergui	80	81	78	79	..	..	78	74	..	71	83	132	..	3	4	NW & SW	
	Shwe-gyeen	72	81	71	72	..	..	72	....	..	....	91	130	..	13	8	S W	
Week ending 10th July 1875	Akyab	82	83	80	81	2	2	91	75	..	...	86	147	..	5	..	Not given	
	Kyouk-phyoo	76	80	73	75	3	4	80	63	..	..	83	138	..	14	6	SE & SW	
	Sandoway	80	81	77	79	3	4	83	76	..	..	83	138	..	11	2	E and W	
	Rangoon	83	80	79	76	4	4	84	74	..	73	84	94	..	1	8	S	
	Bassein	81	81	77	77	4	4	83	75	..	80	86	162	..	3	¼	Not given	
	Henzada	81	82	78	78	3	4	85	75	..	..	82	74	..	4	1	S W	
	Prome	81	83	77	78	4	5	81	75	..	....	84	134	..	...	½	do.	
	Thayetmyo	83	83	79	79	4	4	81	...	..	..	..	..	..	4	..	N W S W	
	Toungoo	80	83	77	80	3	3	87	73	..	...	94	135	..	5	..	Not given	
	Maulmain	79	81	77	78	..	..	84	75	..	55	84	135	..	4	8½	S W	
	Tavoy	77	79	75	86	2	3	89	74	..	...	79	..	..	9	9¾	SW & SE	
	Mergui	81	80	78	77	..	..	86	74	..	75	82	132	..	6	¾	NE & SW	
	Shwe-gyeen	71	81	71	71	..	..	82	..	..	....	91	130	..	9	5	S W	
Week ending 17th July 1875	Akyab	80	80	79	78	1	2	93	75	..	...	83	112	..	18	½	Not given	
	Kyouk-phyoo	77	80	73	75	4	4	83	70	..	...	86	144	..	16	3	SE & SW	
	Sandoway	79	79	77	77	..	..	88	75	..	72	82	117	..	19	4	S E W E	
	Rangoon	82	80	79	76	..	..	84	75	..	79	85	87	..	4	2	S E	
	Bassein	81	81	79	78	..	..	86	78	..	..	86	161	..	2	..	Not given	
	Henzada	81	82	78	79	3	3	87	75	..	...	82	90	..	6	6	S W	
	Prome	81	80	78	79	3	1	91	75	..	..	83	..	..	3	¼	S W	
	Thayetmyo	82	83	79	79	3	4	81	75	..	58	89	129	..	6	..	do.	
	Toungoo	89	81	77	78	3	3	87	74	..	..	84	113	..	5	½	Not given	
	Maulmain	80	82	77	78	..	..	85	74	..	...	83	138	..	8	9	S W	
	Tavoy	80	81	78	77	2	4	87	75	..	...	81	..	..	12	9½	do.	
	Mergui	85	84	79	72	..	..	74	74	..	77	88	150	..	5	..	NE & SW	
	Shwe-gyeen	71	82	71	78	..	..	71	....	..	..	91	130	..	8	5	S W	
Week ending 24th July 1875	Akyab	80	82	78	79	..	..	80	77	..	..	86	141	..	4	25·29	Not given	
	Kyouk-phyoo	80	83	76	79	..	..	80	65	..	..	86	147	..	11	4	SE and W	
	Sandoway	78	77	75	75	..	..	88	75	..	73	81	122	..	29	6	S E S W	
	Rangoon	80	79	77	77	..	..	88	74	..	80	82	91	..	4	·21	SE and S	
	Bassein	80	78	78	76	..	..	86	75	..	..	83	160	..	21	¼	Not given	
	Henzada	80	79	78	77	2	2	91	74	..	..	79	84	..	4	36·25	S W	
	Prome	81	81	78	78	3	3	87	75	..	..	83	..	..	2	..	do.	
	Thayetmyo	82	89	80	79	..	..	83	77	..	59	88	130	..	2	..	do.	
	Toungoo	80	77	78	77	2	..	95	75	..	..	82	144	..	6	...	SW & SE	
	Maulmain	79	80	77	78	..	..	87	73	..	..	82	124	..	17	..	S W	
	Tavoy	77	77	76	75	1	2	93	73	..	...	77	..	..	19	5	SW & SE	
	Mergui	79	77	76	76	..	..	74	73	..	78	83	134	..	13	½	NE & SW	
	Shwe-gyeen	71	81	72	71	..	..	71	....	..	..	91	130	..	14	8	S W	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1875.—Continued.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THERMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 31st July 1875.	Akyab ..	81	80	79	78	2	2	91	75	..	..	83	119	..	18	½	Not given	
	Kyouk-phyoo..	87	86	76	78	..	..	84	62	..	..	83	146	..	15	1	S E & S W	
	Sandoway ..	78	79	76	76	..	..	86	75	..	73	81	131	..	11	5	SSE & SW	
	Rangoon ..	79	79	77	76	..	..	90	73	..	79	82	87	..	3	3	S E	
	Bassein ..	80	80	78	78	..	..	90	75	..	..	85	154	..	4	21	Not given	
	Henzada ..	79	79	77	77	2	2	91	74	..	..	79	85	..	12	1	S W	
	Prome ..	79	80	77	77	2	3	89	74	..	..	81	..	..	3	¾	Do.	
	Thayetmyo ..	81	82	79	79	..	..	86	76	..	69	87	125	..	3	¼	Do.	
	Toungoo ..	78	78	76	76	2	2	91	73	..	..	80	136	..	4	¼	Not given	
	Maulmain ..	79	80	77	78	..	..	85	74	..	..	82	131	..	7	4	S W	
	Tavoy ..	77	79	75	76	2	3	89	72	..	..	79	..	..	4	8	SE & SW	
	Mergui ..	79	79	77	71	2	2	71	73	..	77	83	141	..	4	¾	NE & SW	
	Shwe-gyeen ..	71	82	71	71	..	..	71	..	..	..	91	130	..	10	1	S W	
Week ending 7th Aug. 1875.	Akyab ..	80	82	78	79	2	3	89	74	..	..	81	128	..	10	4	Not given	
	Kyouk-phyoo..	78	78	75	77	..	..	83	64	..	..	83	146	..	6	1	S E & W	
	Sandoway ..	78	79	76	76	..	..	84	74	..	72	82	132	..	9	7	SE & SW	
	Rangoon ..	80	78	77	76	..	..	86	73	..	80	84	84	..	..	20		
	Bassein ..	81	80	78	77	..	..	85	74	..	..	85	148	..	5	¾	Not given	
	Henzada ..	80	81	77	77	3	4	85	75	..	..	81	88	..	4	3·30	S W	
	Prome ..	79	81	77	77	2	4	91	74	..	..	84	..	..	..	1½	S W	
	Thayetmyo ..	82	82	79	79	..	..	83	75	..	67	89	136	..	3	1	N W	
	Toungoo ..	79	80	78	78	1	2	93	74	..	..	82	139	..	3	8	Not given	
	Maulmain ..	80	82	77	78	..	..	83	73	..	..	84	141	..	5	6	S W	
	Tavoy ..	77	79	75	76	2	3	89	73	..	..	79	..	..	.13	8½	SE & SW	
	Mergui ..	82	80	79	79	..	..	75	73	..	78	82	148	..	1	½	NE & NW	
	Shwe-gyeen ..	71	81	71	72	..	..	72	..	..	..	91	130	..	5	5	S W	
Week ending 14th Aug. 75.	Akyab ..	82	83	80	80	2	3	89	75	..	..	86	144	..	4	7	Not given	
	Kyouk-phyoo..	82	85	79	83	..	..	84	66	..	..	87	146	..	8	1	SE & SW	
	Sandoway ..	81	80	77	77	..	..	82	75	..	73	84	137	..	9	5	Do.	
	Rangoon ..	80	80	78	77	..	..	86	74	..	80	83	90	..	..	19	S E	
	Bassein ..	82	80	78	77	..	..	88	74	..	..	85	157	..	2	4	Not given	
	Henzada ..	81	82	78	75	3	7	88	75	..	..	82	93	..	10	1	S W	
	Prome ..	82	84	78	79	4	5	81	75	..	..	85	..	..	1	½	S W	
	Thayetmyo ..	83	83	80	79	..	..	90	75	..	68	89	137	..	1	½	S W	
	Toungoo ..	81	85	79	80	2	5	85	76	..	..	86	149	..	5	2	S E	
	Maulmain ..	81	83	77	79	4	4	81	74	..	..	85	146	..	17	2	S W	
	Tavoy ..	77	78	76	76	1	2	93	73	..	..	78	..	..	14	4	S W	
	Mergui ..	77	79	76	77	..	..	74	72	..	77	80	137	..	6	½	NW & SW	
	Shwe-gyeen ..	72	81	72	71	..	..	71	..	..	..	92	130	..	3	9	S E	
Week ending 21st Aug. -75.	Akyab ..	82	82	79	79	3	3	87	76	..	..	85	140	..	1	3½	Not given	
	Kyouk-phyoo..	80	82	78	78	..	..	86	68	..	..	86	143	..	11	..	SE & SW	
	Sandoway ..	79	79	77	76	..	..	87	76	..	71	82	128	..	12	5	SW & S E	
	Rangoon ..	81	79	78	76	..	..	85	74	..	78	83	85	..	2	18	S E	
	Bassein ..	78	78	77	78	..	..	91	74	..	..	84	146	..	3	2	Not given	
	Henzada ..	81	80	79	77	2	3	89	75	..	..	80	83	..	3	0·31	S W	
	Prome ..	81	82	78	78	3	4	85	75	..	..	85	..	..	..	½	S W	
	Thayetmyo ..	83	83	79	80	..	..	79	76	..	72	91	142	..	..	1½	S W	
	Toungoo ..	80	82	78	78	2	4	87	75	..	..	83	141	..	3	1½	Not given	
	Maulmain ..	78	80	77	77	..	..	88	73	..	..	82	136	..	11	2	S W	
	Tavoy ..	79	80	77	77	2	3	89	74	..	..	81	..	..	6	9	S E & S W	
	Mergui ..	80	79	77	77	..	..	75	76	..	75	83	125	..	11	2¼	NW & SW	
	Shwe-gyeen ..	72	82	70	72	..	..	71	..	..	..	91	116	..	6	6	S W	
Week ending 28th Aug. -75.	Akyab ..	83	84	84	80	1	4	89	74	..	..	86	147	..	4	1½	Not given	
	Kyouk-phyoo..	82	85	85	80	..	..	85	66	..	..	86	141	..	5	8	NE & SW	
	Sandoway ..	81	82	82	77	..	..	81	75	..	73	84	149	..	2	8	SE & SW	
	Rangoon ..	82	84	84	78	..	..	76	75	..	84	86	117	..	..	12	S W	
	Bassein ..	82	81	81	78	..	..	82	75	..	..	87	164	..	..	1	Not given	
	Henzada ..	82	83	83	79	1	4	89	76	..	..	83	91	..	3	1·19	S W	
	Prome ..	82	84	84	78	2	6	83	75	..	..	86	..	..	..	1	S W	
	Thayetmyo ..	84	84	84	80	..	..	80	77	..	78	91	145	..	..	½	S W	
	Toungoo ..	80	82	82	78	2	4	87	75	..	..	85	144	..	4	8	Not given	
	Maulmain ..	81	83	83	78	..	..	80	75	..	..	84	145	..	3	6½	S W	
	Tavoy ..	79	80	80	77	1	3	91	74	..	..	81	..	..	6	9	SW & SE	
	Mergui ..	81	79	79	78	..	..	76	73	..	77	83	122	..	4	4½	NW & SW	
	Shwe-gyeen ..	72	81	81	71	..	..	71	..	..	..	99	130	..	6	..	SW & SE	
Week ending 4th Sep. 1875.	Akyab ..	83	83	80	80	3	3	87	76	..	74	87	142	..	6	2½	E E	
	Kyouk-phyoo.	85	88	81	84	..	..	78	74	..	..	90	160	..	7	7	NE & SE	
	Sandoway ..	81	81	77	77	..	..	82	76	..	73	84	147	..	7	9	SE & SW	
	Rangoon ..	82	79	78	76	..	..	83	74	..	80	85	93	..	1	·24	SW & S	
	Bassein ..	83	80	78	78	..	..	81	74	..	..	87	163	..	3	3½	Not given	
	Henzada ..	82	81	78	78	4	3	85	76	..	..	81	86	..	2	9·49	S W	
	Prome ..	81	83	78	79	3	4	85	75	..	..	85	..	..	1	2	SE & SW	
	Thayetmyo .	84	85	80	79	..	..	78	77	..	72	91	147	..	..	½	S W	
	Toungoo ..	81	84	78	79	3	5	83	76	..	..	85	169	..	..	4·21	Not given	
	Maulmain ..	81	83	78	79	..	..	81	74	..	..	85	144	..	12	1	S W	
	Tavoy ..	78	79	79	76	1	3	91	73	..	..	80	..	..	18	5½	SW & SE	
	Mergui ..	81	80	78	78	..	..	76	72	..	79	84	137	..	3	2	NW & SW	
	Shwe-gyeen ..	71	81	71	71	..	..	71	..	..	..	91	130	..	5	9	S W	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1875—Continued.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THERMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vaccuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 11th Septr. '75	Akyab	82	80	80	78	2	2	91	75	..	73	85	146	..	13	19	NE & SW	
	Kyouk-phyoo	83	88	81	84	..	..	78	74	..	..	90	160	..	10	...	Do.	
	Sandoway	80	78	77	76	..	.	84	76	..	72	83	138	..	14	4	SW & SE	
	Rangoon	79	78	76	76	..	..	86	72	..	79	84	92	..	1	12	S & SW	
	Bassein	82	78	79	76	..	...	87	74	..	...	85	163	..	6	3	Not given	
	Henzada	82	83	78	78	4	5	81	75	..	..	83	93	..	5	3	S W	
	Prome	81	83	77	79	4	5	81	75	..	..	86	..	..	..	1	S W	
	Thayetmyo	83	86	78	80	..	..	76	76	..	76	92	146	..	2	1½	S E	
	Toungoo	81	84	78	79	3	5	83	75	..	..	86	152	..	3	5	Not given	
	Maulmain	78	80	77	77	..	..	88	73	..	...	81	130	..	16	4	S W	
	Tavoy	76	78	75	75	1	5	82	72	..	...	78	..	..	12	2½	S E	
	Mergui	78	76	77	75	..	...	74	72	..	79	81	130	..	6	3½	NW & SW	
	Shwe-gyeen	71	82	71	71	..	..	71	..	..	..	91	130	..	5	4	S W	
Week ending 18th Septr. '75	Akyab	85	83	80	79	5	4	81	77	..	74	88	150	..	..	3	S E	
	Kyouk-phyoo	83	86	80	84	..	..	89	73	..	..	89	159	..	1	8	NE & SW	
	Sandoway	80	79	76	76	..	...	83	74	..	72	83	142	..	9	6	SE & SW	
	Rangoon	80	81	77	76	..	...	81	73	..	80	84	102	..	2	.	S	
	Bassein	82	78	78	76	..	...	86	74	..	..	86	163	..	4	2¾	Not given	
	Henzada	81	83	78	78	3	5	83	74	..	..	83	97	..	1	9	S W	
	Prome	81	84	78	79	3	5	83	75	..	...	85	..	..	1	¾	S W	
	Thayetmyo	84	88	77	80	..	..	68	76	..	72	90	149	..	...	2¼	S E	
	Toungoo	80	82	77	79	3	3	87	95	..	..	87	153	..	1	7	Not given	
	Maulmain	80	82	77	77	..	..	82	74	..	..	85	140	..	5	2½	S W	
	Tavoy	77	79	75	76	2	3	89	72	..	..	79	..	..	8	8¼	S E	
	Mergui	78	78	76	76	..	..	75	73	..	81	81	132	..	4	2¼	NW & SW	
	Shwe-gyeen	71	82	71	71	..	...	71	...	..	....	91	130	..	7	9	S W	
Week ending 25th Septr. '75	Akyab	84	86	79	80	5	6	77	75	..	73	80	152	..	1	1¾	N E	
	Kyouk-phyoo	82	85	79	82	..	...	81	68	..	..	87	156	..	6	8	NE & SW	
	Sandoway	81	83	76	77	..	..	78	75	..	71	85	146	..	4	1	S E W E	
	Rangoon	82	84	78	78	..	...	77	75	..	82	88	105	..	...	1	S	
	Bassein	84	83	79	78	..	...	78	76	..	...	88	167	..	1	..	Not given	
	Henzada	84	88	79	80	5	8	74	77	..	...	88	104	..	..	6	S W	
	Prome	82	86	79	79	3	7	79	76	..	...	88	..	..	..	¼	NW & SW	
	Thayetmyo	86	89	80	83	..	..	74	76	..	73	92	149	..	..	..	S E	
	Toungoo	81	84	78	80	3	4	85	74	..	...	86	146	..	5	9	Not given	
	Maulmain	82	86	78	79	..	..	74	75	..	..	88	149	..	4	9¼	S W	
	Tavoy	79	82	77	78	2	4	87	73	..	...	82	..	..	4	½	SE & NW	
	Mergui	82	80	79	78	..	...	77	80	..	82	84	145	..	2	1¾	NW & SW	
	Shwe-gyeen	71	81	72	71	..	..	71	..	..	..	91	130	..	6	9	SE & SW	
Week ending 2nd Octr. 1875	Akyab	84	86	79	80	5	6	77	77	..	74	88	151	..	..	¾	E & S	
	Kyouk-phyoo	75	79	72	75	..	..	81	63	..	..	82	141	..	1	5	NE & NW	
	Sandoway	82	84	77	79	..	..	78	77	..	72	86	150	..	2	1·22	NE & SW	
	Rangoon	80	80	77	77	..	.	84	74	..	81	84	95	..	..	·10	S	
	Bassein	84	81	79	78	..	..	85	75	..	..	87	161	..	1	1·01	Not given	
	Henzada	82	83	79	79	3	4	85	76	..	..	83	95	..	1	0·22	S W	
	Prome	82	82	78	80	4	2	87	76	..	..	98	....	..	...	½	SE & SW	
	Thayetmyo	85	87	80	83	..	..	82	76	..	70	94	150	..	..	1·06	S E	
	Toungoo	82	84	79	80	3	4	85	75	..	..	83	151	..	5	6	Not given	
	Maulmain	79	80	77	77	..	..	87	74	..	...	81	125	..	13	3	S W	
	Tavoy	77	78	76	76	1	2	93	73	..	...	78	..	..	12	3¼	S E	
	Mergui	79	78	77	76	..	..	75	79	..	79	83	141	..	6	3	NW & SW	
	Shwe-gyeen	72	82	71	71	..	..	72	...	..	..	91	130	..	4	6	SE & SW	
Week ending 9th Octr. 1875.	Akyab	80	80	78	77	2	3	89	75	..	76	84	122	..	2	2¾	Not given	
	Kyouk-phyoo	84	87	81	85	..	...	82	70	..	..	89	143	..	6	3	SE & NE	
	Sandoway	78	79	76	75	..	..	85	75	..	69	82	135	..	10	8	SW & SE	
	Rangoon	80	80	77	77	..	...	84	74	..	80	84	94	..	..	22	S	
	Bassein	81	81	78	78	..	..	85	74	..	...	83	161	..	...	2·23	Not given	
	Henzada	80	81	78	78	2	3	89	75	..	...	81	90	..	2	2·21	S W	
	Prome	80	81	78	78	2	3	89	74	..	...	84	..	..	1	2·09½	SE & SW	
	Thayetmyo	83	81	79	78	..	..	84	75	..	66	91	141	..	1	½	S E	
	Toungoo	80	81	78	77	2	4	87	75	..	...	84	152	..	3	24	S W	
	Maulmain	81	82	78	78	..	..	81	75	..	..	86	132	..	6	1	S W	
	Tavoy	79	81	77	77	2	4	87	74	..	...	81	...	..	1	8¼	S E	
	Mergui	81	81	78	78	..	...	76	81	..	82	82	146	..	2	2·08	S W	
	Shwe-gyeen	71	82	71	72	..	..	71	...	..	..	92	130	..	2	1	S W	
Week ending 16th Octr. 1875.	Akyab	84	85	77	78	7	7	72	72	..	70	88	144	..	..	¼	Not given	
	Kyouk-phyoo	83	87	80	85	..	...	82	67	..	..	90	147	..	...	..	NW & SW	
	Sandoway	80	82	76	77	..	..	78	75	..	69	85	142	..	..	7·23	NE & SW	
	Rangoon	84	88	77	76	..	..	69	75	..	86	88	104	..	..	4	S E	
	Bassein	83	83	78	79	..	..	76	74	..	...	87	161	..	1	1	Not given	
	Henzada	83	83	78	79	5	4	81	75	..	..	86	104	..	1	·22	NE & SW	
	Prome	80	84	77	79	3	5	83	74	..	...	85	....	..	1	1¼	NE & SW	
	Thayetmyo	85	82	79	79	..	..	79	74	..	64	92	147	..	1	1	S E	
	Toungoo	81	85	78	79	3	6	81	75	..	..	87	151	..	..	4·14	S W	
	Maulmain	83	85	77	79	..	..	72	74	..	..	88	135	..	1	2½	SW & SE	
	Tavoy	78	81	76	76	2	5	85	72	..	..	81	..	..	6	½	NE & SW	
	Mergui	80	80	77	77	..	...	75	80	..	81	84	145	..	5	1	S W	
	Shwe-gyeen	71	81	72	71	..	..	71	..	..	....	91	130	..	..	5	S W	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1875—Continued.

	STATIONS.	Hygrometer in shade. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	Minimum Thermometers. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	Maximum Thermometers. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 23rd Octr. 1875	Akyab ..	85	86	80	79	5	7	76	75	..	72	90	145	..	..	·½	N E	
	Kyouk-phyoo ..	85	88	81	84	...	..	78	74	...	..	90	160	..	..	8	NE & W	
	Sandoway ..	81	84	76	79	..	..	72	75	..	66	86	148	..	..	3·1	SW & SE	
	Rangoon ..	86	86	79	79	..	..	68	75	..	84	91	118	..	..	35	S E	
	Bassein ..	85	86	79	78	...	..	69	73	...	..	89	163	..	3	2	Not given	
	Henzada ...	83	89	79	80	4	9	74	76	..	..	89	122	..	..	...	NE & SW	
	Prome ...	81	84	79	79	2	5	85	75	...	...	87	..	..	..	...	do.	
	Thayetmyo ...	85	83	79	79	..	..	76	76	..	65	94	148	..	..	..	S E	
	Toungoo ...	81	87	78	80	3	7	79	75	...	..	88	153	..	1	9	NE & SW	
	Maulmain ...	85	89	77	79	...	..	61	75	...	..	92	138	..	..	3	N E	
	Tavoy ...	81	84	79	79	2	5	85	72	...	..	84	...	..	..	1½	S W	
	Mergui ..	82	82	78	78	..	..	76	82	...	82	86	145	..	..	¼	S W	
	Shwe-gyeen ..	72	81	71	71	..	..	72	...	...	..	91	130	..	..	..	NE & SW	
Week ending 30th Octr. 1875	Akyab ...	82	84	77	77	5	7	75	72	..	70	87	141	..	..	14	N E	
	Kyouk-phyoo ...	83	86	80	84	..	..	83	73	..	...	89	159	..	..	8	NE & SW	
	Sandoway ...	80	83	75	76	..	..	71	74	...	67	85	143	..	..	6	SE & NW	
	Rangoon ...	84	86	78	77	...	..	67	74	...	..	89	109	..	..	..	S E	
	Bassein ..	85	84	79	77	...	...	70	73	..	..	89	163	..	1	..	Not given	
	Henzada ..	82	88	78	80	4	8	76	74	...	..	88	104	..	1	2	NW & NE	
	Prome ..	80	85	76	79	4	6	79	74	..	..	84	..	..	..	¼	NE & NW	
	Thayetmyo ..	85	83	79	79	..	...	79	74	...	73	94	147	..	..	...	S E	
	Toungoo ..	81	85	76	79	5	6	77	71	...	..	85	154	..	2	1	N & NE	
	Maulmain ..	83	87	78	79	..	..	67	75	..	..	91	133	..	..	..	NW & NE	
	Tavoy ..	82	86	78	79	4	7	77	74	...	..	86	...	..	..	2¼	NE & NW	
	Mergui ..	83	85	79	79	..	..	76	83	...	78	87	143	..	..	¼	S E	
	Shwe-gyeen ..	72	81	72	72	..	...	71	..	..	..	91	130	..	1	1	NE & SW	
Week ending 6th Novr. 1875.	Akyab ..	84	84	78	77	6	7	73	71	..	69	88	146	..	..	...	NE and E	
	Kyouk-phyoo ..	78	81	75	78	3	3	84	66	..	..	86	140	..	1	9	Not given	
	Sandoway ..	80	82	76	76	..	...	79	85	..	66	85	147	..	..	3	NE & SW	
	Rangoon ..	83	85	77	76	..	..	65	72	..	...	88	112	..	2	..	S E	
	Bassein ..	81	82	77	77	..	..	80	72	..	..	88	158	..	..	..	Not given	
	Henzada ..	81	87	77	79	4	8	75	73	..	..	87	108	..	1	2	N E	
	Prome ...	84	85	77	81	4	4	83	72	..	..	86	..	..	..	4½	do.	
	Thayetmyo ..	84	85	80	82	..	..	76	74	..	53	92	141	..	..	¼	S E	
	Toungoo ..	79	85	74	69	5	16	58	72	..	..	86	155	..	..	2	NE & N	
	Maulmain ..	84	87	76	75	..	..	63	72	..	...	91	137	..	..	1	N E	
	Tavoy ..	79	83	74	76	5	7	..	70	..	..	83	...	..	1	¼	NE & SW	
	Mergui ..	82	82	74	78	..	..	75	82	..	81	86	142	..	1	¼	NW and E	
	Shwe-gyeen ..	71	82	71	71	...	..	71	..	..	..	92	130	..	1	..	N E	
Week ending 13th Novr. '75	Akyab ..	81	83	76	74	5	9	71	69	..	66	86	141	..	..	..	NE & E	
	Kyouk-phyoo ..	80	77	71	73	..	...	78	60	..	..	83	132	..	..	...	NE & NW	
	Sandoway ..	78	82	74	75	..	..	73	72	..	65	84	147	..	..	..	NE & SW	
	Rangoon ..	83	84	76	76	..	..	66	61	..	..	88	123	..	..	..	S E	
	Bassein ..	84	80	76	76	..	..	73	70	..	...	88	163	..	..	..	Not given	
	Henzada ..	82	87	77	78	5	9	72	73	..	..	87	103	..	..	..	N E	
	Prome ..	80	85	76	78	4	7	77	73	..	..	87	...	..	..	..	N E	
	Thayetmyo ..	84	87	79	78	..	..	69	70	..	74	92	790	..	..	..	S E	
	Toungoo ..	77	85	74	77	3	8	76	70	..	..	86	151	..	..	..	N N E	
	Maulmain ..	83	87	77	76	..	...	65	73	..	..	91	135	..	2	6½	SE & NE	
	Tavoy ..	80	85	75	77	5	8	73	70	..	..	85	...	..	..	..	NE & NW	
	Mergui ..	83	84	77	78	..	...	75	83	..	81	87	145	..	..	¾	NW & SE	
	Shwe-gyeen ..	71	81	71	71	..	..	72	..	..	..	91	130	..	..	..	N E	
Week ending 20th Novr. -75.	Akyab ..	78	80	73	73	5	7	74	65	..	61	84	137	..	..	..	NE & E	
	Kyouk-phyoo ..	73	75	73	69	...	...	74	62	..	..	79	117	..	..	..	NW & NE	
	Sandoway ..	78	82	73	73	..	...	65	71	..	63	84	146	..	..	..	NE & SW	
	Rangoon ..	83	89	76	75	..	..	61	71	..	..	89	139	..	..	..	S E	
	Bassein ..	83	84	76	75	..	..	64	68	..	...	87	161	..	..	..	Not given	
	Henzada ..	80	87	75	77	...	..	9	73	..	..	87	103	..	..	..	N E	
	Prome ..	79	85	75	76	4	9	73	70	..	..	85	..	..	..	..	NE & SW	
	Thayetmyo ..	80	85	74	78	..	...	71	66	..	51	90	143	..	..	..	S E & N E	
	Toungoo ..	77	84	73	76	4	8	74	69	..	..	85	151	..	..	..	N N E	
	Maulmain ..	84	87	77	76	..	..	60	70	..	..	91	134	..	..	..	NE & SE	
	Tavoy ..	80	84	73	75	7	9	67	67	..	..	85	..	..	..	..	N E & E	
	Mergui ..	83	84	78	76	..	..	70	82	..	80	88	140	..	..	..	NW & E	
	Shwe-gyeen ..	71	82	71	72	..	..	71	..	..	..	91	130	..	..	..	N E & E	
Week ending 27th Novr. -75.	Akyab ..	75	78	71	72	4	6	77	62	..	58	82	132	..	..	..	N N E	
	Kyouk-phyoo ..	76	75	64	67	..	..	77	63	..	..	81	133	..	..	..	NE & NE	
	Sandoway ..	76	80	71	73	5	7	74	69	..	60	83	687	..	..	..	do.	
	Rangoon ..	81	86	74	76	7	10	63	69	..	..	89	135	..	..	..	S E	
	Bassein ..	82	83	74	74	...	...	67	65	..	..	87	150	..	..	..	Not given	
	Henzada ..	76	84	71	75	5	9	70	70	..	..	84	101	..	..	..	N E	
	Prome ..	76	82	70	74	6	8	70	67	..	..	82	..	..	..	..	do.	
	Thayetmyo ..	79	82	72	73	..	..	64	62	..	63	86	142	..	..	..	NE & NW	
	Toungoo ..	71	80	69	72	2	8	77	63	..	..	82	149	..	..	..	N N E	
	Maulmain ..	83	88	76	76	..	..	61	71	..	..	92	137	..	..	..	E & W	
	Tavoy ..	80	86	75	78	5	8	73	69	..	..	87	..	..	..	..	NE & NW	
	Mergui ..	83	85	77	78	..	..	72	83	..	80	88	140	..	..	..	NW & SE	
	Shwe-gyeen ..	71	81	71	71	...	..	71	..	..	..	91	130	..	..	..	N N E	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1875-76.—Continued.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THERMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 4th Dec. 1875.	Akyab	78	67	76	66	2	1	93	63	..	56	83	134	..	..	..	S and E	
	Kyouk-phyoo	78	77	70	73	..	...	78	60	..	..	83	132	..	..	..	NE & NW	
	Sandoway	74	78	66	69	..	...	66	63	..	56	80	141	..	..	..	do.	
	Rangoon	80	86	73	73	..	...	57	65	..	..	88	133	..	..	..	S E	
	Bassein	82	81	73	72	..	...	65	64	..	..	86	160	..	..	..	Not given	
	Henzada	74	84	71	73	3	11	70	65	..	..	85	113	..	..	..	N E	
	Prome	73	81	67	72	6	9	67	63	..	..	82	..	..	..	..	N E	
	Thayetmyo	77	83	70	73	..	...	62	56	..	76	85	142	..	..	..	N E & S E	
	Toungoo	70	80	65	71	5	9	68	59	..	..	80	147	..	..	..	N W	
	Maulmain	83	88	76	76	..	...	59	68	..	..	91	136	..	..	..	E N E	
	Tavoy	81	86	76	79	5	7	75	71	..	..	87	..	..	..	..	SW & NE	
	Mergui	83	86	78	79	..	..	75	84	..	81	89	150	..	..	..	N W & E	
	Shwe-gyeen	72	80	71	72	..	...	72	..	..	..	91	130	..	..	..	N E & E	
Week ending 11th Dec. 75.	Akyab	77	79	72	70	5	9	70	62	..	56	84	137	..	..	..	Not given	
	Kyouk-phyoo	73	76	71	69	..	..	74	62	..	53	79	115	..	..	..	do.	
	Sandoway	75	79	70	70	..	..	63	63	..	..	81	136	..	..	..	N E	
	Rangoon	80	84	72	72	..	...	56	66	..	..	87	132	..	..	..	N E	
	Bassein	83	82	72	74	..	...	58	61	..	..	86	157	..	..	..	Not given	
	Henzada	74	83	69	73	5	10	60	65	..	..	83	113	..	..	..	N E	
	Prome	74	81	68	72	6	9	67	61	..	79	81	..	..	..	..	N E	
	Thayetmyo	76	82	67	71	..	...	55	58	..	..	86	138	..	..	..	N E	
	Toungoo	70	79	65	71	5	8	70	61	..	..	80	149	..	..	..	N E	
	Maulmain	81	86	72	73	..	...	55	66	..	..	89	133	..	..	..	N W	
	Tavoy	77	82	69	71	8	11	60	64	..	..	32	..	..	..	..	S E & W	
	Mergui	80	82	73	75	..	...	70	80	..	77	86	152	..	..	..	N W & E	
	Shwe-gyeen	72	82	71	71	..	..	71	..	..	..	91	130	..	..	..	N E	
Week ending 18th Dec. 75.	Akyab	77	77	69	67	8	10	61	63	..	57	84	135	..	..	..	NE & NW	
	Kyouk-phyoo	66	75	64	67	..	..	67	63	..	..	81	133	..	..	..	N E	
	Sandoway	73	77	64	67	..	...	55	60	..	48	79	137	..	..	..	N N E	
	Rangoon	75	80	65	67	..	...	51	61	..	..	82	127	..	..	..	Not given	
	Bassein	78	78	67	67	..	..	53	58	..	..	82	152	..	..	..	N E	
	Henzada	71	79	66	69	5	10	66	62	..	..	79	105	..	..	..	N E	
	Prome	71	79	65	69	6	10	64	61	..	..	79	..	..	..	..	N E	
	Thayetmyo	74	81	66	68	..	...	55	57	..	66	84	137	..	..	..	N E	
	Toungoo	67	77	63	66	4	11	64	55	..	..	78	144	..	..	..	N E	
	Maulmain	75	81	66	64	..	...	50	61	..	..	84	126	..	..	..	SE & NE	
	Tavoy	74	80	66	70	8	10	61	61	..	..	81	..	..	..	..	N E	
	Mergui	75	81	68	72	..	..	69	77	..	66	84	151	..	..	..	NW & E	
	Shwe-gyeen	71	81	71	72	..	...	72	..	..	..	91	130	..	..	..	N E	
Week ending 25th Dec. 75.	Akyab	74	76	66	66	8	10	60	59	..	52	82	130	..	..	..	N W	
	Kyouk-phyoo	65	68	62	65	..	...	81	62	..	..	80	138	..	..	..	N W	
	Sandoway	71	75	63	66	..	...	58	58	..	44	78	139	..	...	...	N E	
	Rangoon	75	80	64	65	..	...	49	65	..	..	82	126	..	..	..	N E	
	Bassein	78	76	69	66	..	...	54	55	..	..	83	151	..	..	..	Not given	
	Henzada	69	79	64	68	5	11	63	59	..	..	79	101	..	..	..	N E	
	Prome	69	78	63	67	6	11	61	58	..	..	79	..	..	..	..	N E	
	Thayetmyo	71	80	64	66	..	...	50	55	..	72	83	135	..	..	..	N W	
	Toungoo	65	76	62	66	3	10	68	52	..	..	77	146	..	..	..	N N E	
	Maulmain	74	81	63	66	..	..	47	56	..	..	84	128	..	..	..	NE & S E	
	Tavoy	70	78	60	66	10	12	51	55	..	..	78	..	..	..	..	N E	
	Mergui	73	77	64	68	..	...	61	75	..	70	82	151	..	..	..	N E & E	
	Shwe-gyeen	71	81	71	72	..	..	71	..	..	..	91	131	..	..	..	N & N E	
Week ending 1st Jany. 76.	Akyab	73	77	66	66	7	11	60	58	..	50	82	130	..	..	..	N E	
	Kyouk-phyoo	73	75	70	72	..	...	84	64	..	..	84	138	..	..	..	NE & NW	
	Sandoway	69	76	63	65	..	...	58	56	..	36	80	138	..	..	..	E N E	
	Rangoon	76	86	67	69	..	..	48	62	..	..	87	132	..	..	..	N E	
	Bassein	..	..	..	..	..	...	..	..	..	..	..	...	..	..	..	Not given	
	Henzada	70	82	66	70	4	12	64	60	..	..	82	110	..	..	..	N E	
	Prome	70	80	65	68	5	2	82	57	..	..	80	..	..	..	..	N E	
	Thayetmyo	70	80	65	68	..	...	59	53	..	56	84	133	..	..	..	N W	
	Toungoo	64	77	62	69	2	8	75	53	..	..	79	139	..	..	..	N E	
	Maulmain	78	86	68	70	..	..	47	60	..	..	88	134	..	..	..	N E	
	Tavoy	74	84	68	73	6	11	63	63	..	..	84	..	..	..	..	NE & NW	
	Mergui	78	84	72	74	6	10	68	80	..	70	86	152	..	..	..	NE & E	
	Shwe-gyeen	72	80	71	72	..	...	73	..	..	..	91	130	..	..	..	N E	
Week ending 8th Jany. 76.	Akyab	74	76	65	67	9	9	60	57	..	49	83	131	..	..	..	Not given	
	Kyouk-phyoo	82	82	76	79	..	..	75	66	..	..	89	143	..	..	..	NE & NW	
	Sandoway	68	78	65	67	..	..	67	57	..	45	81	138	..	..	..	N E	
	Rangoon	82	89	69	74	..	..	46	68	..	..	92	135	..	..	..	N E	
	Bassein	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Henzada	73	84	68	73	5	11	65	64	..	..	84	104	..	..	..	N E	
	Prome	71	83	66	69	5	4	78	61	..	..	83	..	..	..	..	NE & SW	
	Thayetmyo	70	80	66	68	..	..	68	54	..	57	84	135	..	..	..	N E	
	Toungoo	68	81	64	70	4	11	66	57	..	..	82	137	..	..	..	N E	
	Maulmain	85	89	73	75	..	..	51	68	..	..	93	136	..	..	..	N E	
	Tavoy	79	87	73	77	6	10	67	67	..	..	87	..	..	..	..	N E & W	
	Mergui	82	85	75	78	..	..	72	83	..	77	89	155	..	..	..	NW & SW	
	Shwe-gyeen	82	72	72	74	..	..	73	..	..	..	87	130	..	..	..	N E	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1876—Continued.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THERMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 15th Jany. -76	Akyab	71	76	64	66	7	10	61	53	..	44	81	131	..	..	..	..	
	Kyouk-phyoo	81	85	79	83	..	..	86	66	...	..	86	147	..	..	..	NE & NW	
	Sandoway	65	76	62	65	..	..	65	56	..	39	80	138	..	..	..	E N E	
	Rangoon	81	89	70	71	..	..	44	67	..	62	91	136	..	..	..	N E	
	Bassein	80	84	70	71	..	..	52	60	..	..	89	161	..	..	..	..	
	Henzada	73	85	66	72	7	13	58	61	..	..	85	90	..	..	..	N E	
	Prome	71	84	64	69	7	15	53	59	..	..	85	..	..	..	..	NE & SW	
	Thayetmyo	72	80	66	70	..	..	61	51	..	59	87	133	..	..	..	NE & SE	
	Toungoo	68	81	63	70	5	11	63	56	..	..	82	138	..	..	..	N E & N	
	Maulmain	81	88	69	74	..	..	48	65	..	..	92	133	..	..	..	N E	
	Tavoy	77	85	71	74	6	11	64	65	..	..	85	..	..	..	..	NE NW	
	Mergui	82	85	73	76	..	..	+72	82	..	75	88	155	..	..	..	NE & SW	
	Shwe-gyeen	81	71	72	72	9	1	77	..	..	..	91	130	..	..	..	N E	
Week ending 22nd Jany. -76	Akyab	72	78	64	68	8	10	60	55	..	45	83	132	..	..	..	..	
	Kyouk-phyoo	83	87	80	84	..	..	80	68	..	..	90	152	..	..	..	Not given	
	Sandoway	64	76	63	65	..	..	70	55	..	37	79	137	..	..	..	N E S W	
	Rangoon	77	86	69	70	..	..	48	64	..	59	88	132	..	..	..	E & N E	
	Bassein	78	82	67	69	..	..	52	58	..	..	87	130	..	..	..	NE & SW	
	Henzada	70	82	65	74	5	8	71	60	..	..	82	102	..	..	..	..	
	Prome	70	83	64	66	6	17	51	58	..	..	83	..	..	..	..	N E	
	Thayetmyo	73	84	65	71	..	..	52	52	..	74	87	132	..	..	..	NE & SW	
	Toungoo	67	80	64	67	3	11	67	55	..	..	80	138	..	..	..	S E	
	Maulmain	77	86	69	72	..	..	53	62	..	..	90	130	..	..	..	NE & NW	
	Tavoy	74	84	68	73	6	11	63	60	..	..	84	..	..	..	..	N E S W	
	Mergui	80	84	72	75	..	..	67	81	..	72	87	..	..	..	..	NE & SW	
	Shwe-gyeen	81	71	72	72	..	..	72	..	..	..	91	131	..	..	..	E	
Week ending 29th Jany. -76	Akyab	75	78	67	67	8	11	59	59	..	51	81	134	..	..	..	Not given	
	Kyouk-phyoo	80	83	79	80	..	..	85	68	..	..	86	134	..	..	..	N W	
	Sandoway	67	76	64	65	..	..	69	59	..	47	79	137	..	..	..	E & N E	
	Rangoon	77	84	68	68	..	..	50	63	..	..	88	133	..	..	..	N E	
	Bassein	78	81	69	67	..	..	55	58	..	..	86	160	..	..	..	..	
	Henzada	72	82	67	71	5	11	65	59	..	..	82	106	..	..	..	N E	
	Prome	71	83	64	66	7	17	49	59	..	..	84	..	..	..	..	SW & W	
	Thayetmyo	77	85	67	70	..	..	48	56	..	60	89	134	..	..	..	S W	
	Toungoo	71	80	65	69	6	1	83	58	..	..	81	135	..	..	..	E	
	Maulmain	76	82	67	68	..	..	51	63	..	..	87	132	..	..	..	S E & W	
	Tavoy	73	83	67	71	6	12	61	60	..	..	83	..	..	..	..	N E	
	Mergui	79	82	71	74	..	..	70	80	..	70	87	..	..	..	..	N E & SW	
	Shwe-gyeen	82	72	72	72	..	..	71	..	..	..	91	130	..	..	..	S E	
Week ending 5th Feby. 1876	Akyab	75	78	66	68	9	10	59	59	..	52	83	136	..	..	..	Not given	
	Kyouk-phyoo	76	78	72	75	..	..	82	66	..	..	81	143	..	..	..	N W	
	Sandoway	66	76	64	65	2	11	68	59	..	48	79	137	..	..	..	E & NW	
	Rangoon	78	86	69	69	..	..	47	61	..	..	88	140	..	..	..	SE & SW	
	Bassein	80	80	69	68	..	..	56	60	..	..	86	161	..	..	..	Not given	
	Henzada	71	85	66	69	5	16	55	58	..	..	85	111	..	..	..	N E	
	Prome	72	84	65	67	7	17	50	59	..	..	85	..	..	..	..	SW & NE	
	Thayetmyo	75	82	65	68	..	..	51	54	..	67	87	132	..	..	..	S W	
	Toungoo	71	82	62	68	9	14	51	57	..	..	83	141	..	..	..	S E	
	Maulmain	79	84	69	71	..	..	53	60	..	..	90	132	..	..	..	N W	
	Tavoy	73	83	69	72	4	11	67	61	..	..	82	..	..	..	..	N W	
	Mergui	81	82	73	74	..	..	69	81	..	69	86	..	..	..	..	N W & E	
	Shwe-gyeen	82	72	72	71	..	..	72	..	..	..	91	130	..	..	..	N E	
Week ending 12th Feby. -76.	Akyab	72	78	61	65	11	13	48	52	..	44	82	135	..	..	..	Not given	
	Kyouk-phyoo	71	74	68	71	..	..	83	59	..	..	76	141	..	..	..	N W	
	Sandoway	63	75	60	63	3	12	63	54	..	36	80	139	..	..	..	E & NW	
	Rangoon	80	80	68	70	..	..	43	61	..	..	93	144	..	..	..	N E	
	Bassein	79	81	67	71	..	..	55	59	..	..	90	162	..	..	..	..	
	Henzada	68	87	63	67	5	20	48	53	..	..	87	111	..	..	..	N E	
	Prome	71	88	62	66	9	22	54	55	..	..	88	..	..	..	..	S W	
	Thayetmyo	74	86	63	70	11	16	46	50	..	77	91	136	..	..	..	S W	
	Toungoo	72	85	63	69	9	16	48	53	..	..	86	145	..	..	..	S E	
	Maulmain	81	89	71	72	..	..	48	62	..	..	94	144	..	..	..	N W	
	Tavoy	78	86	72	76	6	10	67	66	..	..	86	..	..	..	..	SW & W	
	Mergui	82	86	76	78	..	..	72	83	..	70	89	..	..	..	..	NW & E	
	Shwe-gyeen	82	72	73	72	..	..	72	..	..	..	92	133	..	..	..	N E	
Week ending 19th Feby. -76.	Akyab	76	79	69	74	7	5	73	61	..	56	84	138	..	..	..	Not given	
	Kyouk-phyoo	75	77	71	74	..	..	80	66	..	..	80	145	..	..	..	N W	
	Sandoway	68	81	65	69	..	..	67	60	..	48	84	141	..	..	..	NE & NW	
	Rangoon	79	91	70	74	..	..	49	65	..	..	94	144	..	..	..	..	
	Bassein	83	85	72	70	..	..	61	61	..	..	92	162	..	..	..	NE & NW	
	Henzada	71	90	63	72	3	18	57	60	..	..	92	113	..	..	..	N E	
	Prome	73	92	67	68	6	14	57	61	..	..	92	..	..	..	..	NE & SW	
	Thayetmyo	80	91	67	70	..	..	44	54	..	60	96	135	..	..	..	S W	
	Toungoo	71	87	63	70	8	17	48	57	..	..	88	144	..	..	..	N E	
	Maulmain	82	89	72	72	..	..	48	65	..	..	97	145	..	..	..	N E	
	Tavoy	76	86	71	74	5	12	64	65	..	..	87	..	..	..	..	N E	
	Mergui	82	84	76	77	..	..	73	83	..	71	89	..	..	..	..	NEW & W	
	Shwe-gyeen	71	82	71	72	..	10	77	..	..	..	91	130	..	..	..	N W	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1876.—Continued.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THERMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 25th Feby. '76.	Akyab	77	80	67	72	10	8	61	60	..	53	81	139	...	..	...	Not given	
	Kyouk-phyoo	75	77	71	74	..	...	79	59	...	..	82	136	..	..	..	N W	
	Sandoway	68	81	63	67	..	..	56	59	...	50	84	141	..	..	..	E & N W	
	Rangoon	82	91	71	72	..	..	44	65	...	...	92	143	..	..	..	N E	
	Bassein	84	86	69	69	..	...	54	63	..	..	91	161	..	..	..	Not given	
	Henzada	73	89	67	71	6	18	52	61	..	..	89	111	..	..	..	N E	
	Prome	76	90	65	68	11	22	38	61	..	...	91	..	..	..	...	NE & SW	
	Thayetmyo	78	90	65	70	..	..	43	56	..	89	94	137	...	..	..	N E	
	Toungoo	72	86	65	69	7	17	51	57	..	..	87	147	..	..	..	SE & NE	
	Maulmain	82	89	71	72	..	..	49	65	...	..	95	145	..	..	..	N E	
	Tavoy	78	87	70	74	8	13	58	63	..	..	88	...	..	..	...	NE and W	
	Mergui	85	86	77	77	..	..	72	85	..	72	91	..	..	..	..	NW and E	
	Shwe-gyeen	82	73	72	72	..	..	71	..	...	..	92	133	..	..	..	NE & SE	
Week ending 4th March '76.	Akyab	79	82	72	73	7	9	66	62	..	53	88	141	..	..	..	Not given	
	Kyouk-phyoo	76	80	74	77	..	..	82	67	..	...	83	131	..	..	..	NE & NW	
	Sandoway	74	83	66	73	8	10	61	62	..	51	86	142	..	..	..		
	Rangoon	81	97	71	70	..	..	41	66	..	..	99	147	..	..	...	N and SW	
	Bassein	88	87	72	71	...	..	45	66	..	..	94	166	..	..	..	Not given	
	Henzada	73	93	68	72	5	21	49	60	...	..	93	115	..	..	...	N E	
	Prome	78	95	68	69	10	26	36	64	...	..	96	..	..	..	..	SW and W	
	Thayetmyo	82	95	69	83	..	..	43	57	...	84	100	142	..	..	..	S W	
	Toungoo	74	91	66	72	8	19	47	59	..	..	92	151	..	..	..	S E	
	Maulmain	83	94	73	73	..	..	42	67	..	..	97	149	..	..	..	NE & SW	
	Tavoy	78	88	72	77	6	11	65	66	..	..	88	...	..	..	..	NE & NW	
	Mergui	86	87	78	79	..	..	75	86	..	75	91	..	..	..	...	N W	
	Shwe-gyeen	82	73	71	72	..	..	71	..	..	..	93	132	..	..	..	N E	
Week ending 11th March '76	Akyab	83	84	73	74	10	10	60	66	..	59	80	144	..	..	..		
	Kyouk-phyoo	82	84	76	79	..	..	77	66	...	..	89	148	..	..	..	N W N E	
	Sandoway	76	84	70	75	..	..	64	63	..	54	86	144	..	..	..	N E	
	Rangoon	84	96	74	76	..	..	45	71	..	...	99	16	..	..	..	S W	
	Bassein	87	89	74	73	..	..	48	70	..	..	95	167	..	..	..		
	Henzada	77	95	71	73	6	22	48	66	...	..	95	118	..	..	..	S W	
	Prome	81	96	70	73	11	24	39	67	...	..	97	..	..	..	..	S W W	
	Thayetmyo	84	97	72	75	..	..	42	68	..	83	101	141	..	..	..	S W N W	
	Toungoo	76	93	66	73	10	20	44	63	...	..	94	141	..	..	..	S E	
	Maulmain	87	91	76	75	..	..	50	74	..	...	97	149	..	..	..	N E N W	
	Tavoy	82	91	75	77	7	14	60	71	..	..	91	...	..	..	..	S W W	
	Mergui	87	92	79	80	..	...	74	88	..	76	94	..	..	..	..	S W	
	Shwe-gyeen	72	81	72	73	..	..	72	..	..	..	90	135	..	..	..	N E	
Week ending 18th March '76	Akyab	85	84	85	75	10	9	62	69	..	65	90	144	..	..	...	N E	
	Kyouk-phyoo	81	85	79	83	...	..	85	66	..	..	88	147	..	..	..	S E	
	Sandoway	80	85	72	76	..	..	61	66	..	55	87	145	..	..	..	S W	
	Rangoon	86	96	78	75	...	..	49	71	..	..	103	149	..	..	..		
	Bassein	89	87	75	75	..	...	49	72	..	...	94	166	..	...	..	N E	
	Henzada	81	96	73	76	8	20	49	69	..	..	96	115	..	..	..	N W	
	Prome	85	98	72	73	13	25	36	71	..	..	99	...	..	..	..	do.	
	Thayetmyo	90	98	74	75	..	...	47	69	..	78	103	745	..	..	..	S E	
	Toungoo	83	96	67	73	16	23	34	67	..	..	96	156	..	..	..	N E	
	Maulmain	86	88	75	77	..	..	56	74	..	..	94	147	..	..	...		
	Tavoy	82	89	78	78	4	11	70	72	..	..	90	...	..	..	..	S E S W	
	Mergui	88	88	80	79	..	..	74	88	..	79	91	..	..	..	..	N W	
	Shwe-gyeen	72	82	71	73	...	..	72	..	..	..	90	134	..	..	..	do.	
Week ending 25th March '76	Akyab	85	85	75	78	10	7	66	72	..	68	91	146	..	..	..	N W	
	Kyouk-phyoo	83	87	80	84	..	..	80	68	..	..	90	135	..	...	..	N E	
	Sandoway	82	85	73	76	..	..	59	69	..	60	87	146	..	..	..	S W	
	Rangoon	86	93	75	79	..	..	51	70	..	..	100	147	..	..	..	S	
	Bassein	88	93	75	75	..	...	50	73	..	...	96	163	..	..	..	N E	
	Henzada	83	95	75	76	8	19	51	71	..	..	95	117	..	..	...	N W	
	Prome	85	97	74	74	11	23	42	74	..	..	97	..	..	..	..	S W	
	Thayetmyo	90	98	75	77	..	..	44	70	..	88	103	143	..	..	...	S E	
	Toungoo	83	98	69	74	14	19	41	71	..	..	94	159	..	...	..	N W	
	Maulmain	85	88	77	76	..	..	64	74	..	..	94	147	..	..	..	N E	
	Tavoy	84	90	77	79	7	11	65	74	..	..	91	..	..	..	..	N W	
	Mergui	88	90	80	81	...	..	74	88	..	78	93	..	..	...	..	N E	
	Shwe-gyeen	72	61	70	72	...	..	71	..	..	..	91	134	..	..	..		
Week ending 1st April 1876.	Akyab	86	86	78	78	8	8	68	74	..	70	91	145	..	..	..	N W	
	Kyouk-phyoo	80	84	75	75	..	..	68	68	..	..	87	145	..	...	..	N E N W	
	Sandoway	83	85	74	76	...	..	61	73	..	65	87	146	..	..	..	S W	
	Rangoon	89	94	77	79	..	..	51	70	..	..	100	147	..	..	..		
	Bassein	88	90	75	76	..	..	82	72	..	..	95	160	..	..	..	N E	
	Henzada	84	95	76	77	8	18	53	72	..	..	95	109	..	..	..	S W W	
	Prome	85	97	74	75	11	22	43	76	..	..	98	..	..	..	..	S W	
	Thayetmyo	93	99	78	81	..	...	50	75	..	86	103	144	..	..	..	S S E	
	Toungoo	84	94	76	79	8	15	57	75	..	..	95	160	..	..	..	N	
	Maulmain	86	89	77	76	..	..	57	76	..	..	93	149	..	...	..	N E W	
	Tavoy	84	90	77	79	7	11	65	72	..	..	91	..	..	..	..	N W	
	Mergui	86	89	82	81	..	..	75	86	..	79	92	..	..	...	..	N E N W	
	Shwe-gyeen	83	72	72	72	..	..	72	..	..	..	92	136	..	..	..		

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1876.—Continued.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THERMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 8th April 1876.	Akyab	88	87	79	80	9	7	69	73	..	69	92	147	..	..	..	E N E	
	Kyouk-phyoo	81	83	74	77	..	..	65	64	...	...	85	148	..	..	..	N E W	
	Sandoway	83	87	76	77	..	..	62	74	...	66	87	177	..	..	..	N E	
	Rangoon	88	94	78	82	..	..	61	75	...	72	100	152	..	..	..	S W	
	Bassein	90	93	76	76	..	..	46	74	..	...	97	140	..	..	..		
	Henzada	84	98	77	78	7	20	52	73	..	..	98	113	..	..	..	N E	
	Prome	87	100	77	77	10	23	45	74	..	...	101	..	..	..	..	S W N	
	Thayetmyo	93	101	75	77	..	..	44	74	..	80	105	146	..	..	..	S W	
	Toungoo	85	97	76	78	9	19	51	75	..	...	97	159	..	..	..	SE & NE	
	Maulmain	88	90	79	77	..	..	69	76	...	..	95	147	..	..	..	E & SW	
	Tavoy	84	90	78	80	6	10	69	85	..	..	91	..	..	..	..		
	Mergui	89	90	80	82	..	..	77	85	..	78	92	..	..	..	..	N W	
	Shwe-gyeen	83	74	72	73	..	..	72	..	...	..	90	138	..	..	..	NE & NW	
Week ending 15th April '76.	Akyab	88	87	79	79	9	8	67	74	..	69	91	149	..	..	..	S	
	Kyouk-phyoo	82	86	77	80	..	..	75	65	..	..	87	149	..	..	..	NE NW	
	Sandoway	84	87	75	77	..	...	60	75	..	67	89	146	..	..	..	Do.	
	Rangoon	88	92	77	78	..	..	54	75	..	73	98	155	..	..	5·10	S W	
	Bassein	90	92	76	76	..	..	45	73	..	..	96	162	..	..	...		
	Henzada	83	97	77	78	6	19	55	74	..	...	97	111	..	..	6	S W	
	Prome	86	97	76	75	10	22	45	77	...	...	99	..	..	..	..	S W W	
	Thayetmyo	92	100	78	79	..	..	44	77	...	83	104	139	..	..	..	S W	
	Toungoo	87	96	78	78	9	18	32	76	..	...	97	160	..	..	..	N E	
	Maulmain	87	90	77	77	..	..	56	76	..	..	95	152	..	..	..	E S W	
	Tavoy	84	89	78	79	6	10	68	77	..	..	89	..	..	..	...	NW & NE	
	Mergui	85	87	80	80	..	..	76	83	..	75	92	..	..	3	08	N W E	
	Shwe-gyeen	82	73	75	74	..	...	74	..	..	..	90	133	..	..	..	NE & NW	
Week ending 22nd April-76	Akyab	89	88	81	88	..	..	69	88	..	68	75	148	..	..	9	S W	
	Kyouk-phyoo	85	87	84	86	..	..	84	76	...	..	70	154	..	..	..	N W	
	Sandoway	85	88	78	86	..	..	63	76	..	68	76	148	..	..	..	NE & NW	
	Rangoon	89	91	79	90	..	..	61	..	..	74	76	158	..	1	4	S W	
	Bassein	91	93	77	92	..	..	49	90	..	...	75	161	..	..	..		
	Henzada	87	99	79	93	..	..	50	85	...	..	75	117	..	..	..	SE & SW	
	Prome	86	98	76	92	..	..	51	87	...	..	79	..	..	..	...	S W & N	
	Thayetmyo	92	101	80	96	..	..	46	94	..	91	78	150	..	..	..	S W	
	Toungoo	87	97	78	92	..	...	52	97	..	..	77	160	..	1	2	N N E	
	Maulmain	88	90	78	89	..	..	59	88	..	..	76	155	..	..	..	E N E	
	Tavoy	84	90	80	87	..	..	68	83	..	..	76	..	..	..	94	NE & SE	
	Mergui	87	88	81	87	..	..	74	88	..	...	84	..	..	5	8	N W E	
	Shwe-gyeen	73	80	72	76	..	..	72	..	..	..	..	133	..	..	5	S W	
Week ending 29th April '76.	Akyab	91	89	82	90	..	..	71	89	..	73	77	153	..	..	..	S S W	
	Kyouk-phyoo	84	86	82	85	..	..	82	85	..	..	71	148	..	..	..	NE & NW	
	Sandoway	85	89	77	87	..	..	63	86	..	67	76	148	..	..	...	Do.	
	Rangoon	89	90	79	89	..	..	61	..	..	65	77	160	..	..	..	S W	
	Bassein	91	89	78	90	..	..	56	85	..	...	75	169	..	..	7		
	Henzada	91	97	78	94	..	..	46	89	..	..	77	113	..	..	..	S W	
	Prome	89	98	78	93	..	..	47	89	..	...	81	..	..	..	..	S W W	
	Thayetmyo	94	101	83	97	..	..	48	95	..	81	80	151	..	..	..	S W	
	Toungoo	88	96	79	92	..	..	52	96	..	..	79	159	..	..	..	E & N E	
	Maulmain	87	88	77	87	..	..	63	87	..	..	76	153	..	1	6	S W	
	Tavoy	85	37	81	86	..	..	69	82	..	..	74	..	..	3	1	Variable	
	Mergui	86	88	81	87	..	..	75	88	..	75	84	..	..	2	3	S W E	
	Shwe-gyeen	80	79	74	79	..	..	83	..	..	..	..	139	..	1	6	S W	
Week ending 6th May 1876.	Akyab	89	88	82	82	..	..	74	84	..	75	78	154	..	3	..	S W	
	Kyouk-phyoo	84	87	80	84	..	..	64	73	..	..	70	143	..	2	4	N E	
	Sandoway	86	90	78	79	..	..	62	78	..	69	78	151	..	..	..	N E N W	
	Rangoon	89	88	79	79	..	..	63	..	..	76	77	157	..	1	64	S W	
	Bassein	89	86	78	81	..	..	65	80	..	..	76	164	..	4	1	SW & S E	
	Henzada	90	91	79	78	..	..	58	88	..	..	73	103	..	..	3	S W	
	Prome	90	96	79	78	..	..	54	89	..	..	80	..	..	..	..	S W W	
	Thayetmyo	94	98	82	83	..	..	54	93	..	95	80	152	..	1	6	S W	
	Toungoo	87	96	78	81	..	..	59	96	..	...	77	147	..	..	9	E	
	Maulmain	87	89	78	78	..	..	65	86	..	..	75	155	..	1	5	S W	
	Tavoy	86	89	78	79	..	..	66	88	..	..	74	..	..	..	..		
	Mergui	86	85	80	79	..	..	74	85	..	75	83	80	..	2	9	S W E	
	Shwe-gyeen	71	81	70	72	..	..	81	..	..	..	..	134	..	1	1	S W	
Week ending 13th May 1876.	Akyab	89	89	82	82	..	..	71	79	..	76	93	147	..	1	6	SS and E	
	Kyouk-phyoo	82	85	78	81	..	..	83	67	..	..	89	147	..	..	8	N E	
	Sandoway	84	85	79	78	..	..	73	78	..	71	89	143	..	1	9	NE & NW	
	Rangoon	82	84	78	79	..	..	77	76	..	75	86	140	..	5	..	S W	
	Bassein	84	83	79	79	..	..	81	76	..	..	88	145	..	1	17	do.	
	Henzada	85	86	80	79	..	..	76	76	..	..	86	95	..	1	¼	S E	
	Prome	85	90	79	79	..	..	67	79	..	..	94	..	..	..	6	S W	
	Thayetmyo	90	95	81	83	..	..	58	79	..	87	101	152	..	..	..	S W	
	Toungoo	84	94	79	80	..	..	64	77	..	..	94	143	..	1	3	S E	
	Maulmain	82	81	77	88	..	..	84	76	..	..	86	135	..	4	¼	S W	
	Tavoy	79	81	77	77	..	...	88	74	..	..	81	..	..	15	7¾	Variable	
	Mergui	80	79	80	77	..	..	92	79	..	77	83	..	..	13	12	S W E	
	Shwe-gyeen	73	82	71	73	..	..	75	..	..	..	89	134	..	5	..	SW & SE	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1876.—Continued.

	STATIONS.	Hygrometer in shade. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity, per cent., saturation being represented by 100.	Minimum Thermometers. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	Maximum Thermometers. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 20th May 1876.	Akyab	86	88	79	80	..	..	71	93	..	62	92	147	..	3	...	S E	
	Kyouk-phyoo	83	86	80	83	..	..	86	69	...	..	89	144	..	5	4	N E	
	Sandoway	81	86	76	77	..	..	69	77	..	72	86	142	..	3	6	NE & NW	
	Rangoon	83	83	78	78	..	..	81	76	..	75	87	155	..	4	..	S W	
	Bassein	85	86	79	79	..	...	73	75	..	...	91	157	..	2	6	S W W	
	Henzada	84	83	79	78	..	..	78	75	..	...	83	89	...	2	7	S W	
	Prome	83	87	78	78	..	..	71	77	..	..	91	..	..	1	...	S W	
	Thayetmyo	88	95	81	82	..	..	73	78	...	79	101	152	...	..	..	S W	
	Toungoo	87	92	80	81	..	..	63	75	..	..	97	155	...	..	2	S E	
	Maulmain	80	81	77	77	..	..	85	73	..	..	85	121	..	6	7	S W	
	Tavoy	78	79	76	76	..	..	89	72	..	...	80	..	..	7	7	Variable	
	Mergui	82	79	79	77	..	..	89	79	..	75	85	....	..	6	8	S W E	
	Shwe-gyeen	72	80	72	73	..	..	83	..	..	..	88	133	..	4	8	S W	
Week ending 27th May 1876.	Akyab	87	86	81	80	..	..	77	77	..	73	91	148	..	...	2	S S E	
	Kyouk-phyoo	84	87	81	85	..	..	87	70	..	..	89	146	..	..	5	SE & SW	
	Sandoway	81	86	77	76	..	..	71	76	..	73	86	142	..	2	7	NE & NW	
	Rangoon	83	80	79	76	..	..	83	76	..	74	87	137	..	5	3	S W	
	Bassein	85	84	80	78	..	..	78	75	..	..	88	156	..	2	3	NW & NE	
	Henzada	84	84	79	79	..	..	79	76	..	..	84	89	..	1	3	S W	
	Prome	84	87	78	79	..	..	72	78	..	..	91	..	..	..	3	S W	
	Thayetmyo	88	90	80	81	..	..	65	78	..	80	98	155	...	..	6	SW & NE	
	Toungoo	85	87	78	79	..	..	71	75	..	..	94	145	..	2	2	S E	
	Maulmain	82	82	78	77	..	..	81	74	..	...	89	149	..	3	8	S W	
	Tavoy	81	82	78	79	..	..	85	74	..	..	83	..	..	3	8¾	Variable.	
	Mergui	82	84	79	80	..	..	84	81	..	75	86	..	..	4	5	S W E	
	Shwe-gyeen	74	82	72	74	..	..	75	....	..	....	91	131	..	1	7	S W	
Week ending 3rd June 1876.	Akyab	85	87	80	81	..	..	77	77	..	74	91	145	..	2	9	E	
	Kyouk-phyoo	80	84	77	80	3	4	85	69	..	...	89	150	...	1	31	N E	
	Sandoway	82	83	77	78	..	...	78	77	..	73	87	143	..	1	6	NE & SW	
	Rangoon	84	83	79	78	..	...	81	76	..	75	87	151	...	1	9	S W	
	Bassein	85	84	80	79	..	...	78	75	..	..	89	160	..	2	7	Variable.	
	Henzada	83	84	79	79	..	..	81	75	..	..	84	93	..	4	2	S W	
	Prome	81	85	79	80	..	..	82	77	..	...	87	..	..	3	4	S W	
	Thayetmyo	85	87	80	82	..	..	79	76	..	78	93	150	..	3	..	S W	
	Toungoo	86	91	81	80	..	..	70	79	..	..	93	155	..	1	8	S E E	
	Maulmain	83	84	79	79	..	..	79	75	..	..	88	150	...	8	8	S W	
	Tavoy	80	82	78	78	..	..	85	74	..	...	83	..	..	6	42¾	Variable.	
	Mergui	82	83	79	79	..	..	84	81	..	76	86	150	..	6	6	S W E	
	Shwe-gyeen	74	81	72	73	..	..	77	..	..	..	91	132	..	1	5	S W	
Week ending 10th June 76.	Akyab	83	82	80	80	..	..	90	75	..	76	86	148	..	15	1	S S E	
	Kyouk-phyoo	83	85	79	80	..	..	84	68	..	..	87	156	..	6	3	N E	
	Sandoway	81	82	79	79	..	..	86	77	..	73	86	139	..	3	3	N E	
	Rangoon	84	83	80	79	..	...	83	77	..	72	87	145	..	1	2		
	Bassein	86	84	81	80	..	..	80	77	..	..	89	158	..	1	7	SW & SE	
	Henzada	85	85	80	80	..	..	80	77	..	..	85	89	..	2	..	S W	
	Prome	84	84	78	79	..	..	80	78	..	..	90	..	...	1	4	do.	
	Thayetmyo	87	85	82	81	..	..	80	79	..	82	94	147	..	2	1½	do.	
	Toungoo	86	89	81	80	..	..	72	75	..	..	85	154	..	1	2	S E	
	Maulmain	84	84	79	79	..	..	81	76	..	..	89	145	...	5	3	S W	
	Tavoy	82	84	79	80	..	..	81	75	..	..	75	..	..	4	4¾	Variable.	
	Mergui	85	85	81	81	..	..	81	82	..	75	89	145	..	2	0	S W E	
	Shwe-gyeen	72	81	71	72	..	..	78	....	..	..	91	132	...	3	9	S W	
Week ending 17th June 76.	Akyab	83	85	85	80	..	..	85	77	..	76	88	141	..	5	...	S	
	Kyouk-phyoo	83	86	86	80	..	..	87	73	..	..	89	159	..	4	4	NE & NW	
	Sandoway	82	81	81	78	..	..	80	78	..	73	85	141	..	6	6	N E	
	Rangoon	82	81	81	79	..	..	85	76	..	75	85	135	..	4	0	S W	
	Bassein	83	82	82	79	..	..	84	76	..	..	87	157	..	5	0	SE & SW	
	Henzada	83	84	84	79	..	..	81	76	..	...	84	94	..	2	2	S W	
	Prome	83	86	86	78	..	..	75	78	..	...	89	..	..	...	4½	S W	
	Thayetmyo	86	87	87	81	..	...	77	77	..	77	93	143	..	..	2	S W	
	Toungoo	78	80	80	76	..	..	88	73	..	...	84	136	...	1	4	S E	
	Maulmain	81	83	83	78	..	..	84	75	..	...	87	144	..	10	..	S W	
	Tavoy	79	80	80	77	..	..	87	75	..	...	82	..	...	10	8		
	Mergui	81	80	80	78	..	..	90	81	..	76	85	136	..	7	2	S W E	
	Shwe-gyeen	73	82	82	72	..	..	78	....	..	....	92	132	..	6	9	S W	
Week ending 24th June 76.	Akyab	81	82	79	79	2	3	86	76	..	75	86	139	..	11	24	S S E	
	Kyouk-phyoo	78	78	75	77	3	1	83	64	..	..	83	146	..	11	9	SE & SW	
	Sandoway	80	80	77	77	3	3	89	75	..	71	83	129	..	16	3	N E	
	Rangoon	82	80	79	78	3	2	86	76	75	75	87	144	11	4	27	S W	
	Bassein	82	82	79	79	3	3	84	76	..	..	87	147	..	5	44	S E	
	Henzada	83	80	79	78	4	2	87	75	..	...	80	82	..	6	8	S W	
	Prome	81	82	78	78	3	4	82	76	..	...	86	..	..	4	5¼	S W	
	Thayetmyo	84	83	80	80	4	3	84	77	..	77	89	147	..	1	96	S W	
	Toungoo	78	79	76	78	2	1	92	74	..	..	83	128	..	2	7	S E	
	Maulmain	80	81	77	77	2	3	86	74	..	..	86	146	12	13	11	S W	
	Tavoy	..	..	76	78	1	2	95	73	..	..	81	..	8	9	5¾	S E	
	Mergui	81	82	79	78	2	4	86	80	..	76	84	138	..	4	24	S W E	
	Shwe-gyeen	73	82	72	74	1	8	80	..	..	....	91	132	..	7	5	S W	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1876.—Continued.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THERMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 1st July 1876.	Akyab	84	85	81	81	3	4	84	77	..	76	88	146	..	5	48	S E	
	Kyouk-phyoo	80	84	76	79	4	5	76	65	..	..	85	148	..	2	35	S E S W	
	Sandoway	80	81	78	77	2	4	88	76	..	72	84	129	..	7	39	NW & NE	
	Rangoon	81	80	79	77	2	3	88	76	74	75	85	133	8	2	54	S W	
	Bassein	84	82	80	79	4	3	84	76	..	..	85	145	..	1	6	SE & SW	
	Henzada	83	82	80	79	3	3	84	76	..	..	82	86	..	5	6	S W	
	Prome	82	83	78	78	4	5	81	77	..	..	87	..	..	...	30	do.	
	Thayetmyo	84	84	80	81	4	3	84	77	..	79	90	146	..	...	96	do.	
	Toungoo	79	82	76	79	3	3	86	74	..	..	83	140	..	1	23	S E	
	Maulmain	78	82	76	78	2	4	89	74	..	..	85	141	11	11	35	S W	
	Tavoy	..	..	76	77	1	2	95	73	..	78	80	..	7	12	7½	S E	
	Mergui	81	79	78	77	3	2	88	79	..	..	81	135	..	12	45	S W E	
	Shwe-gyeen	72	82	72	73	..	9	79	..	..	..	92	132	..	4	2	S W	
Week ending 8th July 1876.	Akyab	80	81	78	79	2	2	91	75	72	75	84	117	101	11	35		
	Kyouk-phyoo	82	83	79	80	3	3	87	67	..	60	86	144	..	3	1		
	Sandoway	79	80	77	77	2	3	90	75	..	78	82	136	..	10	18	S E	
	Rangoon	80	81	77	77	3	4	83	75	74	74	83	136	8	5	69	S W	
	Bassein	80	79	78	76	2	3	86	75	..	..	86	150	11	12	12	S S E	
	Henzada	82	81	79	79	3	2	89	75	..	..	81	86	5	5	09	S W	
	Prome	81	81	78	77	3	3	87	75	..	..	85	..	..	2	22	do.	
	Thayetmyo	83	85	79	80	4	5	79	77	..	77	89	145	..	1	63	SW & SE	
	Toungoo	71	82	79	81	2	1	95	75	..	..	91	142	..	4	10	S E	
	Maulmain	80	80	77	77	3	3	89	74	..	..	84	135	10	7	04	S W	
	Tavoy	..	..	76	77	1	3	94	73	..	..	81	..	8	12	6½	S E	
	Mergui	81	81	78	78	3	3	76	80	..	87	85	132	4	5	64	S W E	
	Shwe-gyeen	72	81	72	73	..	8	81	..	..	..	91	132	..	4	9		
Week ending 15th July 1876	Akyab	78	81	77	78	1	3	90	74	71	74	84	123	104	14	08		
	Kyouk-phyoo	83	85	88	83	3	2	87	69	..	61	86	147	..	17	1		
	Sandoway	78	76	75	75	3	2	90	80	73	66	81	..	..	20	17		
	Rangoon	79	81·3	77·3	77	2	3	86	74	73	74	84	142	9	7	62	S W	
	Bassein	80	80	77	77	2	3	86	74	..	..	85	147	10	10	34		
	Henzada	81	81	78	77	3	3	87	75	..	..	81	83	2	3	3	do.	
	Prome	81	81	77	77	1	1	82	75	..	..	84	..	..	1	..	do.	
	Thayetmyo	83	85	80	80	3	5	63	77	..	75	88	144	12	1	30	do.	
	Toungoo	78	79	76	77	2	2	89	72·9	..	..	79·9	138	7	7	40		
	Maulmain	77	80	76	76	1	3	88	73	..	..	83	136	10	13	83		
	Tavoy	..	..	75·7	75	1	2	96	72·7	..	..	78·7	...	5·9	9	6	S E	
	Mergui	79	79	77·7	77	1	2	76	78	..	80	83	128	4	6	70		
	Shwe-gyeen	72	82	72	73	..	9	72	..	..	..	92	132	..	11	21	S W	
Week ending 22nd July 1876	Akyab	81	81	79	78	2	2	89	74	70	74	84	114	106	17	69		
	Kyouk-phyoo	80	82	77	80	2	2	77	68	..	66	84	147	..	22	..		
	Sandoway	77	79	76	77	1	2	90	81	74	66	82	..	..	14	8	S W	
	Rangoon	81	78	79	76	2	1	90	74	73	74	74	142	9	5	28	do.	
	Bassein	71	81	78	78	3	3	85	75	..	..	85	142	9	7	97	do.	
	Henzada	81	81	79	78	2	2	87	75	..	..	81	82	1	5	02	do.	
	Prome	80	71	77	78	1	1	90	76	..	..	83	..	..	2	50	do.	
	Thayetmyo	81	81	78	79	2	2	75	75	..	73	88	146	12	3	35	SE & S W	
	Toungoo	88	88	77	79	6	9	65	75	..	..	86	145	11	6	30	Do.	
	Maulmain	78	80	76	77	2	2	90	72	..	..	84	129	12	14	..	S W	
	Tavoy	..	..	76	77	1	2	96	72	..	..	80	...	8	6	1½	S E	
	Mergui	78	79	77	76	1	1	75	78	..	79	82	126	3	8	23	S W E	
	Shwe-gyeen	72	81	72	73	1	8	72	..	..	..	93	..	..	9	3	W	
Week ending 29th July 1876	Akyab	80	82	79	79	1	3	88	75	71	75	84	127	106	7	3		
	Kyouk-phyoo	82	84	78	81	4	3	83	65	..	67	85	142	..	9	2		
	Sandoway	78	79	76	77	2	2	90	81	75	65	82	..	..	14	7	S E	
	Rangoon	79	79	78	77	1	2	90	74	73	74	84	147	9	6	66	S W	
	Bassein	80	79	77	76	3	3	87	74	..	..	84	138	10	4	93	do.	
	Henzada	80	79	77	77	3	2	86	75	..	..	79	81	1	7	09	do.	
	Prome	82	82	78	78	4	4	82	76	..	..	84	..	..	2	17	do.	
	Thayetmyo	83	85	79	80	4	5	64	76	..	76	88	138	11	2	33	do.	
	Toungoo	80	81	78	78	2	3	87	76	..	..	86	143	9	4	60	S E	
	Maulmain	79	79	76	76	3	3	90	73	..	..	86	142	13	14	17	S W	
	Tavoy	77	77	76	77	1	..	96	73	..	..	79	..	6	13	5½	S E S	
	Mergui	79	84	77	78	2	9	76	77	..	85	83	128	7	12	18	S W S	
	Shwe-gyeen	72	82	72	73	..	6	72	..	..	..	92	..	..	11	4	S W	
Week ending 5th Augt.-76	Akyab	85	84	81	81	4	3	85	77	73	77	89	150	119	2	12		
	Kyouk-phyoo	81	83	79	80	2	3	87	66	..	70	86	147	..	3	9		
	Sandoway	80	83	78	79	2	4	86	83	77	66	85	..	..	3	11	S E	
	Rangoon	84	85	80	80	4	5	80	77	76	76	88	148	11	1	20	S W	
	Bassein	86	88	80	79	6	9	68	77	..	..	91	165	3	...	..	W	
	Henzada	85	87	80	79	5	8	72	77	..	..	87	94	7	1	91	S W	
	Prome	84	86	78	80	6	6	75	78	..	..	88	..	..	..	59½	SW & NW	
	Thayetmyo	85	86	80	81	5	5	79	77	..	81	91	138	14	...	52	S W	
	Toungoo	83	84	79	80	4	4	81	75	..	..	89	145	13	3	15	S E.	
	Maulmain	81	83	78	79	3	4	86	76	..	..	86	138	10	2	68	S W	
	Tavoy	80	81	78	79	2	2	95	74	..	..	82	..	7	6	4½	Do.	
	Mergui	83	82	80	79	3	3	77	80	..	87	87	147	6	3	95	S W E	
	Shwe-gyeen	72	81	72	73	..	8	81	..	..	..	93	..	..	5	13	S W	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1876—Continued.

	STATIONS.	Hygrometer in Shade. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	Minimum Thermometers. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	Maximum Thermometers. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 12th Augt. '76.	Akyab	83	83	79	79	4	4	85	76	73	75	88	144	116	5	16	..	
	Kyouk-phyoo	81	84	78	81	3	3	87	66	..	68	85	147	..	7	80	..	
	Sandoway	81	81	78	77	3	4	82	82	77	66	84	..	..	5	20	S E	
	Rangoon	81	80	78	77	3	3	86	76	74	75	85	146	9	5	15	S W	
	Bassein	82	81	78	78	4	3	83	76	..	..	86	150	10	1	83	S E	
	Henzada	82	85	78	78	4	5	82	76	..	..	86	131	45	1	85	S W	
	Prome	83	82	78	78	5	4	82	76	..	..	86	..	..	4	95½	do.	
	Thayetmyo	84	84	80	80	4	4	83	77	..	80	90	137	13	3	86	do.	
	Toungoo	84	89	79	81	3	8	78	76	..	..	91	143	14	3	66	S E	
	Maulmain	80	80	77	77	3	3	86	74	..	..	85	139	11	5	59	S W	
	Tavoy	78	78	76	78	2	..	95	72	..	..	80	..	7	5	38½	S E	
	Mergui	81	81	78	77	3	4	76	80	..	84	86	142	6	5	20	S W	
	Shwe-gyeen	72	81	72	73	...	8	95	..	..	..	93	..	..	6	41	do.	
Week ending 19th Augt. '76.	Akyab	81	81	79	79	2	2	87	75	72	75	86	140	113	11	63	..	
	Kyouk-phyoo	81	83	78	81	3	2	87	65	..	67	85	143	..	13	..	..	
	Sandoway	77	78	75	75	2	3	86	78	76	65	80	..	..	15	33	S E S W	
	Rangoon	79	79	79	76	2	3	88	76	74	73	83	134	7	4	92	S W	
	Bassein	81	80	78	77	3	3	86	74	..	..	85	147	10	7	13	S S W	
	Henzada	80	81	78	77	2	4	86	74	..	..	83	111	28	2	96	S W	
	Prome	81	81	77	78	4	3	82	75	..	..	85	..	..	3	37	do.	
	Thayetmyo	83	83	79	79	4	4	83	76	..	75	88	132	11	1	95	do.	
	Toungoo	87	91	81	82	6	9	70	77	..	..	94	144	17	4	8	S E	
	Maulmain	78	79	75	75	3	4	90	72	..	..	83	124	10	11	90	S W	
	Tavoy	77	79	76	76	1	1	97	72	..	..	78	..	5	16	2¼	S E	
	Mergui	79	79	77	77	2	2	88	79	..	75	84	111	5	8	01	S W E	
	Shwe-gyeen	72	81	72	73	..	8	79	...	..	..	93	..	..	6	4	S W	
Week ending 26th Augt. '76.	Akyab	82	83	78	79	4	4	82	75	71	75	86	142	114	3	2	..	
	Kyouk-phyoo	81	84	78	81	3	3	87	68	..	70	87	151	..	2	..	..	
	Sandoway	80	82	78	78	2	4	86	83	76	65	84	..	..	..	8	..	
	Rangoon	81	81	79	78	2	3	84	74	73	74	85	147	10	3	35	S E	
	Bassein	80	80	78	77	2	3	89	75	..	...	85	147	10	..	16	S W	
	Henzada	81	85	78	79	3	6	78	75	..	..	86	132	46	2	67	S W E	
	Prome	81	83	77	79	4	4	82	76	..	..	85	..	..	1	45	S W	
	Thayetmyo	83	85	79	80	4	5	69	75	..	79	89	144	13	..	40	do.	
	Toungoo	83	90	80	82	3	8	77	75	..	..	93	146	18	1	92	do.	
	Maulmain	78	79	76	77	2	2	90	74	..	..	84	121	9	16	01	S E	
	Tavoy	77	78	76	77	1	1	97	73	..	..	79	..	5	9	29	S W	
	Mergui	80	80	78	76	2	4	95	79	..	72	86	130	6	5	49	S E	
	Shwe-gyeen	72	81	72	73	...	8	81	..	..	..	93	..	..	9	26	S W E	
																	S W	
Week ending 2nd Septr. '76.	Akyab	83	82	79	78	4	3	82	76	71	74	78	138	..	9	99	..	
	Kyouk-phyoo	80	82	78	80	1	1	91	70	..	66	87	148	..	7	..	..	
	Sandoway	78	78	76	77	2	1	90	82	77	65	84	..	..	6	22	S E	
	Rangoon	80	79	79	76	2	2	85	74	73	73	84	145	9	5	22	S W	
	Bassein	80	78	77	76	3	2	88	74	..	...	82	138	8	9	15	do.	Cloudy and rain
	Henzada	81	82	77	78	3	4	82	75	..	..	85	121	35	4	11	do.	Cloudy
	Prome	81	82	78	74	3	4	78	76	..	..	85	..	..	4	41½	do.	Slight rain
	Thayetmyo	84	84	79	79	5	5	79	75	..	75	89	138	13	..	88	do.	
	Toungoo	88	85	79	80	4	4	80	74	..	..	88	148	13	5	16	S E	Sunny
	Maulmain	79	80	76	77	2	3	88	73	..	..	86	140	12	11	48	S W	Thunder and lightning
	Tavoy	75	76	74	76	07	03	98	70	..	...	78	..	6	11	25	S E	Calm
	Mergui	78	79	76	76	1	2	88	78	..	74	81	110	3	10	64	S W E	Nimbus thunder & lightning
	Shwe-gyeen	72	82	72	73	1	8	77	...	..	..	93	cldy	..	7	32	S W	Heavy rain
Week ending 9th Septr. '76.	Akyab	82	82	78	78	3	3	82	75	71	77	86	143	..	10	36	..	
	Kyouk-phyoo	80	80	78	77	1	2	86	83	77	...	86	..	..	..	..	c k m b g	
	Sandoway	82	84	78	87	3	2	95	68	..	66	87	151	..	9	25	N E	
	Rangoon	81	80	78	77	2	2	88	74	73	74	84	140	9	2	7	..	c u b
	Bassein	81	79	78	77	3	2	86	74	..	...	84	160	9	6	88	..	
	Henzada	80	83	78	79	3	4	80	75	..	..	86	131	45	1	07	S W	Cloudy and rain
	Prome	81	82	78	78	2	4	86	76	..	..	85	..	..	1	96	do.	Cloudy and drizzly
	Thayetmyo	83	85	79	79	4	5	79	75	..	76	89	139	14	..	79½	S W E	Thunder lightning & rain
	Toungoo	84	83	79	81	4	4	78	75	..	...	91	142	15	3	90	..	
	Maulmain	87	79	76	76	2	1	90	73	..	..	83	139	18	12	12	S E	Cloudy and sunny
	Tavoy	87	80	76	77	2	3	84	72	..	..	80	..	8	3	70	S W	
	Mergui	80	79	77	77	3	2	88	79	..	75	84	120	7	5	7¼	S E	
	Shwe-gyeen	72	82	72	72	1	9	77	..	..	..	93	..	..	4	20¼	S E W	
																23	S E	Rainy
Week ending 16th Septr. '76.	Akyab	86	88	80	78	6	4	79	77	72	75	89	148	..	1	18	..	
	Kyouk-phyoo	85	86	80	84	3	2	85	69	..	72	87	153	..	6	..	c k m b g	
	Sandoway	81	80	78	78	2	1	91	82	76	..	93	..	..	..	..	c i b	
	Rangoon	78	78	76	76	2	2	89	74	73	74	81	131	6	1	24	S N E	
	Bassein	80	79	77	77	3	2	90	74	..	..	83	146	9	4	17	S W	
	Henzada	80	81	78	77	2	3	86	75	..	..	84	123	38	4	87	Variable.	Rain
	Prome	80	82	77	78	2	2	80	76	..	..	85	..	..	3	66	S W	Do.
	Thayetmyo	84	87	80	80	4	5	79	76	..	80	89	133	..	1	81	do.	Thunder lightn ing & rain
	Toungoo	84	92	80	82	3	10	71	76	..	...	93	147	16	1	54	S W S E	
	Maulmain	89	77	77	75	1	2	90	73	..	..	83	140	10	3	78	N E	Cloudy and sunny
	Tavoy	87	78	75	76	1	1	88	72	..	..	78	..	6	4	91	S W	
	Mergui	89	78	77	76	2	1	88	79	..	75	82	106	2	8	..	Variable.	
	Shwe-gyeen	82	82	73	72	..	9	77	..	..	..	93	..	..	6	92	S W E	Nimbus
															2	21	S W	Heavy rain

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1876—Continued.

	STATIONS.	Hygrometer in shade. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet-Bulb. 10 a.m.	Wet-Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	Minimum Thermometers. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	Maximum Thermometers. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 23rd Septr. -76.	Akyab	82	84	78	79	3	4	79	76	72	75	87	149	..	7	9	..	c k m b
	Kyouk-phyoo	82	84	79	82	2	2	85	67	..	70	86	148	..	4	2	..	c i b
	Sandoway	81	80	80	78	1	1	95	83	79	..	82	..	..	2	19	W	
	Rangoon	81	82	78	78	3	3	85	75	74	74	84	140	8	..	73	..	
	Bassein	82	80	78	78	3	2	86	75	..	..	87	152	11	1	97	Variable	Cloudy
	Henzada	82	83	79	79	3	4	80	75	..	..	86	121	37	1	9	S W	do.
	Prome	82	83	76	79	3	4	76	..	..	86	..	..	..	2	14½	S W	Thunder lightning and rain
	Thayetmyo	84	85	79	79	5	6	79	76	..	79	92	143	15	..	95	S W	Strong wind
	Toungoo	83	89	80	82	3	7	76	74	..	..	91	145	17	1	67	S E	Sunny and cloudy
	Maulmain	79	80	76	76	2	3	86	74	..	..	84	144	10	4	20	S W	Cloudy
	Tavoy	79	80	77	78	1	2	88	72	..	..	81	..	8	4	8	S E	Cunnulo stratus
	Mergui	81	80	78	77	3	2	84	80	..	75	85	113	5	1	95	S W E	Rainy
	Shwe-gyeen	72	82	72	72	1	9	77	..	..	..	93	..	..	2	38	S W	
Week ending 30th Septr. -76.	Akyab	85	84	80	79	5	5	79	76	72	75	89	151	..	1	30	..	c k m b
	Kyouk-phyoo	84	85	81	84	3	2	85	69	..	72	89	..	..	..	..	..	c i b
	Sandoway	81	80	79	79	1	1	95	82	79	..	83	153	..	..	45	W	
	Rangoon	81	81	78	78	3	5	81	75	74	73	86	151	10	3	37	S	
	Bassein	83	82	79	78	4	4	82	74	..	..	87	163	12	1	73	S S E	Fair
	Henzada	82	85	79	79	4	5	81	75	..	..	87	129	42	..	9	S W	do.
	Prome	81	86	78	79	3	6	77	76	..	..	87	..	..	..	5	S W N E	Cloudy
	Thayetmyo	86	90	79	80	6	9	45	65	..	89	93	146	17	1	24	S W	
	Toungoo	84	92	80	82	3	9	72	74	..	..	92	147	18	1	..	S E	Sunny
	Maulmain	81	82	78	78	3	3	84	74	..	..	88	152	14	3	32	S W	Thunder and lightning
	Tavoy	80	84	77	79	2	4	80	73	..	..	85	..	11	1	9	S E S W	Cunnulo stratus
	Mergui	80	80	77	77	2	3	84	80	..	75	84	123	3	4	35	N W E	
	Shwe-gyeen	72	82	72	72	1	10	77	..	..	..	93	96	..	2	6	S W	Rainy
Week ending 7th Octr. 1876.	Akyab	86	87	80	80	6	6	75	76	71	73	91	148	..	2	24	..	c k u b
	Kyouk-phyoo	84	86	80	84	3	2	85	70	..	72	88	150	..	1	8	N E	c i b
	Sandoway	84	85	79	80	5	4	79	85	75	..	85	..	..	..	..	W	
	Rangoon	86	86	80	80	5	6	75	77	75	75	89	152	12	..	18	S E	
	Bassein	84	82	79	78	5	4	78	75	..	..	87	151	12	2	19	Variable	Fair
	Henzada	84	88	80	81	4	7	74	77	..	..	90	134	44	..	3	S W	Fair
	Prome	83	87	79	79	4	8	73	78	..	..	89	..	..	..	..	N E S W	Close
	Thayetmyo	88	90	80	79	7	10	62	75	..	73	93	145	18	..	..	S W	
	Toungoo	86	94	81	82	4	11	66	74	..	..	95	149	20	..	10	N E	Sunny
	Maulmain	86	86	79	79	6	5	77	75	..	..	92	153	17	..	34	S W	Foggy
	Tavoy	81	83	78	80	3	3	85	74	..	..	84	..	9	1	8	N E	
	Mergui	81	79	78	77	3	2	84	80	..	73	86	134	5	7	02	N W E	Cloudy
	Shwe-gyeen	85	88	82	87	3	2	87	..	..	..	92	102	..	..	..	S W	Clear
Week ending 14th Octr. -76.	Akyab	83	84	79	78	4	5	78	75	70	71	88	144	..	1	90	..	c k m b
	Kyouk-phyoo	82	85	79	83	2	2	89	66	..	68	88	144	..	5	15	N E	c i b
	Sandoway	82	82	79	79	3	3	87	84	77	..	82	..	..	7	16	W	
	Rangoon	81	83	78	79	3	3	84	75	73	72	86	151	11	1	86	N W N E	
	Bassein	81	82	78	79	3	4	86	74	..	..	86	148	12	2	62	S W	Cloudy
	Henzada	82	85	78	78	3	6	76	74	..	..	87	128	40	2	5	N E	Fair
	Prome	80	83	77	79	3	4	86	75	..	..	86	..	..	2	19	N E S W	Cloudy
	Thayetmyo	83	84	77	77	6	7	75	77	..	..	89	136	12	3	51	S W	
	Toungoo	86	91	80	82	5	9	69	75	..	..	92	150	17	..	68	N E	Sunny
	Maulmain	83	85	78	79	5	6	75	75	..	..	89	150	14	..	77	S E S W	Cloudy and foggy
	Tavoy	80	82	77	79	2	2	84	72	..	..	83	..	10	3	20½	N W S W	
	Mergui	82	80	78	77	3	3	80	81	..	..	86	141	6	2	40	N W E	
	Shwe-gyeen	80	83	79	81	2	1	85	..	..	..	92	104	..	1	10	S W	Rainy
Week ending 21st Octr. 1876	Akyab	82	85	86	78	6	7	87	69	66	68	88	145	..	..	..	..	c b
	Kyouk-phyoo	83	85	80	82	3	3	85	66	..	68	86	146	..	1	..	N E	c u b
	Sandoway	82	86	78	80	4	5	81	85	79	..	83	..	..	..	..	N W	
	Rangoon	85	88	80	80	5	7	72	75	73	73	90	151	13	..	..	..	
	Bassein	85	87	79	79	6	8	72	74	..	..	90	564	15	..	..	N N E	Fair
	Henzada	84	91	78	81	5	11	70	75	..	..	92	137	45	..	..	N E	
	Prome	82	87	77	79	5	8	77	75	..	..	88	..	..	..	..	N E S W	Cloudy and close
	Thayetmyo	86	88	77	78	9	10	61	73	..	70	91	144	20	..	..	S W	
	Toungoo	85	90	80	81	4	9	69	71	..	..	91	155	19	..	..	N E	Sunny
	Maulmain	85	87	80	80	5	7	75	74	..	..	92	152	18	..	32	S W	Cloudy
	Tavoy	82	82	79	79	3	3	85	74	..	..	86	..	11	1	6½	S E N W	
	Mergui	82	83	79	78	3	4	93	80	..	76	87	146	6	2	97	N W E	Fog cunnulo stratus
	Shwe-gyeen	83	89	81	84	2	4	82	..	..	..	93	166	..	..	..	S W	
Week ending 28th Octr. -76.	Akyab	84	87	78	79	6	7	71	72	68	69	91	142	..	..	..	..	c k b
	Kyouk-phyoo	79	82	75	79	4	3	84	66	..	68	86	145	..	..	..	N E	c u b
	Sandoway	82	86	77	79	5	6	78	87	83	..	82	..	..	..	..	W	
	Rangoon	86	85	80	78	6	6	74	74	73	71	89	155	14	..	6	..	
	Bassein	86	86	78	78	7	7	68	73	..	..	90	163	16	..	34	S & E	Fair
	Henzada	83	89	77	80	6	9	75	75	..	..	90	133	43	..	..	N E	do.
	Prome	82	88	76	79	6	8	68	75	..	..	88	..	..	..	..	NE & SW	
	Thayetmyo	85	90	74	75	11	12	86	70	..	78	93	149	23	..	..	S W	
	Toungoo	85	91	80	82	4	9	71	66	..	..	92	150	26	..	..	N E	Sunny
	Maulmain	86	88	79	80	2	8	70	74	..	..	93	149	19	..	54	do.	
	Tavoy	81	84	78	80	3	4	85	74	..	..	87	..	13	1	17½	Slight air	
	Mergui	82	81	77	78	5	5	75	81	..	71	89	153	8	1	72	N W & E	Cunnulo stratus
	Shwe-gyeen	83	89	80	83	3	5	79	..	..	..	92	104	..	1	5	S W	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1876—Continued.

	STATIONS.	Hygrometer in shade. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	Minimum thermometers. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	Maximum thermometers. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 4th Nov. 1876.	Akyab	81	82	75	75	6	6	74	72	66	70	86	135	..	2	18	..	
	Kyouk-phyoo	83	85	80	83	3	2	87	59	..	..	88	146	..	19	..	N E W	c s b
	Sandoway	81	85	78	79	3	6	81	85	82	72	83	..	..	..	6	W	
	Rangoon	83	83	78	78	5	5	81	73	71	71	87	150	14	2	62	..	
	Bassein	82	82	78	78	4	4	82	73	..	..	86	156	13	2	80	S E E	Cloudy and rain
	Henzada	81	84	77	79	4	5	81	73	..	..	85	120	35	3	25	N E	Rainy
	Prome	78	82	75	77	3	5	82	74	..	..	80	..	..	1	64	S W N E	Cloudy
	Thayetmyo	81	84	76	78	5	6	78	72	..	76	88	130	16	1	30	S E	
	Toungoo	84	91	80	82	4	9	71	69	..	..	92	157	23	2	20	N E	Sunny
	Maulmain	87	89	78	79	7	9	66	73	..	..	94	151	21	..	18	N E S E	
	Tavoy	81	84	76	79	5	5	91	76	..	..	87	..	11	..	..	S W	
	Mergui	84	83	79	78	5	5	75	82	..	73	87	144	6	..	12	N W E	Cloudy
	Shwe-gyeen	82	88	79	85	2	3	72	..	..	..	93	101	..	2	9	S E	Clear
Week ending 11th Nov. 76.	Akyab	80	81	75	75	5	6	93	68	65	65	86	139	..	..	..	..	
	Kyouk-phyoo	80	82	77	79	3	3	88	69	..	..	86	141	..	..	..	N E	c s b
	Sandoway	79	85	74	78	5	7	78	80	78	71	84	..	..	..	..	W	
	Rangoon	85	86	80	79	5	7	75	74	72	70	88	150	14	..	..	..	
	Bassein	84	87	78	78	6	9	68	72	..	..	89	162	16	..	37	N E E	Fair
	Henzada	82	89	77	79	5	10	79	73	..	..	90	132	41	..	..	N E	
	Prome	80	85	75	77	5	8	82	70	..	..	85	..	..	..	..	N E	Cloudy
	Thayetmyo	84	87	75	76	9	11	80	67	..	80	91	143	23	..	..	S W	
	Toungoo	84	90	79	83	5	7	75	68	..	..	91	156	22	..	..	N E E	Sunny
	Maulmain	86	89	79	80	7	9	68	73	..	..	94	150	20	..	..	S E N E	
	Tavoy	82	85	75	80	7	5	82	72	..	..	88	..	15	1	2	N E	
	Mergui	83	83	78	78	5	5	97	80	..	68	88	152	7	..	4	S W E	c s
	Shwe-gyeen	82	90	79	86	3	4	69	..	..	..	92	101	..	..	2	N E	Clear
Week ending 18th Nov. 76.	Akyab	78	78	73	73	5	5	97	70	65	67	82	117	..	3	94	..	
	Kyouk-phyoo	76	78	71	74	5	4	73	60	..	..	79	143	..	54	..	N E W	
	Sandoway	78	81	75	76	3	5	88	79	77	68	80	..	..	2	43	N W	
	Rangoon	83	82	78	79	5	3	93	73	72	70	85	151	12	1	68	..	
	Bassein	81	81	76	77	5	4	93	72	..	..	85	149	12	1	42	N E S E	
	Henzada	80	83	76	77	4	6	88	72	..	..	85	118	33	1	4	N E	
	Prome	76	79	74	75	2	4	90	71	..	..	81	..	..	..	84½	N E	
	Thayetmyo	79	82	74	75	5	7	88	70	..	74	88	133	17	2	42	N W	Cloudy
	Toungoo	82	92	80	81	2	11	69	65	..	..	93	155	28	..	45	N E	
	Maulmain	85	85	78	78	7	7	73	72	..	..	92	145	20	..	38	N E S E	
	Tavoy	81	84	75	79	6	5	84	73	..	..	87	..	14	..	..	S W	
	Mergui	84	86	79	79	5	7	76	73	..	79	90	167	15	..	60	S W	Cloudy
	Shwe-gyeen	81	89	78	84	3	5	72	..	..	..	92	104	..	1	4	E & N E	
Week ending 25th Nov. 76.	Akyab	77	78	71	72	6	6	95	67	67	65	82	117	..	1	15	..	
	Kyouk-phyoo	74	77	71	77	3	..	75	61	..	..	79	136	..	2·5	..	N E	
	Sandoway	76	80	73	74	3	6	76	78	75	73	79	..	..	1	56	N W	
	Rangoon	76	79	73	76	3	3	76	70	67	68	82	133	12	3·72	..	N E	
	Bassein	75	78	71	73	4	5	78	67	..	..	80	144	11	1	30	N E E	
	Henzada	74	77	71	73	3	4	75	65	..	..	76	106	28	1	21	N W	
	Prome	72	75	68	71	4	4	83	68	..	..	76	..	..	..	67½	N W	
	Thayetmyo	71	73	68	8	3	5	94	65	..	64	80	105	15	1	47½	N W	
	Toungoo	81	86	78	80	3	6	80	67	..	..	80	151	21	..	16	N	
	Maulmain	84	81	77	77	7	4	73	71	..	..	91	150	20	1	13	N E	
	Tavoy	80	82	73	78	7	4	80	71	..	..	86	..	15	..	5½	Slight air	
	Mergui	82	82	77	77	5	5	75	69	..	75	86	146	17	..	41½	S W	
	Shwe-gyeen	75	80	73	78	2	2	77	..	..	..	90	103	..	..	2	S E	
Week ending 2nd Dec. 1876.	Akyab	77	78	72	71	5	7	97	64	67	52	82	133	..	..	37	..	
	Kyouk-phyoo	74	77	71	74	3	3	86	64	..	..	80	137	..	..	..	N N W	c k b
	Sandoway	75	81	72	81	3	..	64	76	75	63	79	..	..	..	2	N W	
	Rangoon	79	82	72	75	7	7	78	66	65	65	84	146	16	..	..	N E N N E	
	Bassein	80	83	73	74	7	9	88	67	..	..	85	162	19	..	..	N W	
	Henzada	77	83	71	75	6	8	77	66	..	..	83	122	38	..	..	N W	
	Prome	74	78	70	72	4	6	83	67	..	..	79	..	..	..	..	N E	
	Thayetmyo	77	80	70	72	7	8	83	63	..	67	83	127	20	..	..	N W	
	Toungoo	85	89	78	82	7	7	79	62	..	..	90	155	28	..	..	N E	
	Maulmain	81	84	76	77	5	7	76	71	..	..	89	143	18	0	0·2	do.	
	Tavoy	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Mergui	82	83	78	78	4	5	95	72	..	72	87	141	15	1	27	S W	
	Shwe-gyeen	75	81	73	79	2	2	74	..	..	..	84	164	21	..	..	E	
Week ending 9th Dec. 1876.	Akyab	74	76	68	68	5	7	95	60	59	55	81	136	..	..	..	..	c b
	Kyouk-phyoo	72	75	69	72	3	3	83	64	..	..	83	136	..	..	..	N W	
	Sandoway	70	76	66	75	3	5	70	74	72	62	80	..	..	..	..	W	
	Rangoon	79	83	73	75	6	7	71	51	64	60	85	148	19	..	..	N E	
	Bassein	78	82	70	71	8	10	88	63	..	..	84	159	21	..	..	N E E	
	Henzada	76	84	69	73	6	10	71	64	..	..	84	120	35	..	..	N W	
	Prome	72	80	68	69	3	11	78	64	..	..	81	..	..	..	..	N E	
	Thayetmyo	77	82	71	73	5	9	84	60	..	62	84	131	24	..	..	N W	
	Toungoo	81	90	79	80	2	9	79	60	..	..	91	153	30	..	..	N E	
	Maulmain	83	85	74	74	9	11	60	68	..	..	90	140	22	..	..	..	
	Tavoy	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Mergui	81	84	74	76	6	7	71	70	..	67	85	155	14	..	87	S E N W	
	Shwe-gyeen	75	82	73	77	..	2	..	..	..	..	85	104	94	..	..	N E	

Results of Meteorological Observations made at the undermentioned stations in the province of British Burma during the year 1876.—Concluded.

	STATIONS.	HYGROMETER IN SHADE. Dry Bulb. 10 a.m.	Dry Bulb. 4 p.m.	Wet Bulb. 10 a.m.	Wet Bulb. 4 p.m.	Difference. 10 a.m.	Difference. 4 p.m.	Equivalent humidity per cent., saturation being represented by 100.	MINIMUM THERMOMETERS. Dry Minimum. 10 a.m.	Wet Minimum. 10 a.m.	Grass Minimum. 10 a.m.	MAXIMUM THERMOMETERS. Dry Maximum in shade. 4 p.m.	Sun Maximum in vacuo. 4 p.m.	Range in shade.	Rainfall. Inches.	Rainfall. Cents.	Direction of wind.	Clouds weather and other Remarks.
Week ending 16th Decr. -76.	Akyab	75	75	68	67	7	8	97	59	58	55	80	132	..	..	..	..	c b
	Kyouk-phyoo.	75	78	72	75	2	3	88	64	..	..	85	140	..	..	..	N W	
	Sandoway	71	77	66	71	3	6	76	73	71	62	79	77	..	..	..	W	
	Rangoon	79	80	72	73	5	6	69	66	61	58	83	145	20	..	..	N E	
	Bassein	76	80	69	70	8	10	88	60	..	..	82	159	22	..	..	Valuable	
	Henzada	74	82	68	72	5	10	73	63	..	..	82	119	37	..	..	N E	
	Prome	71	78	67	70	4	8	76	63	..	..	81	..	..	..	..	do.	
	Thayetmyo	75	80	67	68	7	10	85	55	..	62	82	131	26	..	..	do.	
	Toungoo	83	70	80	82	3	8	79	60	..	..	91	164	31	..	..	do.	Sunny
	Maulmain	77	84	69	71	7	12	60	65	..	..	87	143	23	..	..	S W N E	
	Tavoy	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Mergui	80	82	72	75	7	7	68	69	..	69	82	162	13	..	..	N N W	Fair
	Shwe-gyeen	70	11	67	77	..	3	73	..	..	..	84	103	..	..	..	E	
Week ending 23rd Decr. -76.	Akyab	72	77	65	66	7	10	82	59	56	52	80	125	..	..	..	..	c b
	Kyouk-phyoo.	74	77	72	74	2	3	88	66	..	..	84	142	..	..	..	N W	
	Sandoway	70	76	64	68	5	7	78	74	69	64	80	..	..	..	..	E & N	
	Rangoon	76	81	67	70	9	10	58	62	62	52	83	148	21	..	..	N E E	
	Bassein	75	80	66	68	8	11	81	59	61	86	82	157	22	..	..	Variable	
	Henzada	72	81	66	71	6	9	90	61	..	..	81	116	34	..	..	N E	
	Prome	70	77	65	69	5	9	71	61	..	..	79	..	..	..	..	do.	
	Thayetmyo	75	80	65	67	9	13	83	53	..	60	82	132	28	..	..	N W	
	Toungoo	82	90	79	81	3	8	88	59	..	..	91	151	31	..	..	N	Fogs
	Maulmain	77	84	65	72	11	11	54	61	..	..	89	139	27	..	..	N E	
	Tavoy	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	
	Mergui	80	82	70	72	10	10	65	78	..	60	83	4	4	..	..	N N E	
	Shwe-gyeen	71	80	66	79	..	2	73	..	..	..	84	..	..	..	..	N E	
Week ending 30th Decr. -76.	Akyab	74	77	67	68	6	9	87	59	58	52	82	127	..	..	..	..	
	Kyouk-phy oo.	75	78	72	74	2	3	86	65	..	..	85	143	..	..	..	N W	
	Sandoway	70	78	65	69	5	9	71	72	70	64	81	..	..	..	..	N & W	
	Rangoon	78	82	70	71	7	10	61	63	62	54	84	148	21	..	..	N E N	
	Bassein	77	82	68	69	8	12	68	61	59	55	84	145	24	..	..	E N E	
	Henzada	74	84	68	73	5	11	67	62	..	..	84	122	37	..	..	N W	
	Prome	72	81	68	68	4	10	88	63	..	..	81	..	..	..	..	N E	
	Thayetmyo	75	80	66	67	8	13	85	55	..	64	84	134	28	..	..	N W	
	Toungoo	83	88	79	82	3	5	87	57	..	..	89	143	31	..	..	N N E	
	Maulmain	76	84	67	70	9	14	52	62	..	..	89	141	27	..	..	N E	
	Tavoy	78	81	67	72	6	7	85	59	..	..	83	..	24	..	..	S W	
	Mergui	81	80	71	74	9	9	66	78	..	60	82	161	3	..	..	N W	
	Shwe-gyeen	69	81	69	79	..	1	74	..	..	..	85	104	94	..	..	E	

SUPPLEMENTS TO PARTS I AND II.

A.

Later information regarding the Sanpo and Brahmaputra Rivers and Thibet.

Further information regarding the Sanpo, furnished by General Wallker, Surveyor General of India.

(a). Part I of this report was mostly written in 1877; and, early in 1878, an abstract was drawn up at the request of Mr. C. U. Aitchison, Chief Commissioner of British Burma, who forwarded it to Major General Walker, Surveyor General of India, with a view to obtain his comments, or any further information on the topics broached. General Walker, in reply, stated that the subject of the outlet of the Sanpo was one in which he had long taken a keen personal interest, and that he was then actually investigating the question on the Bramahputra side through special surveys being made under Captain Woodthorpe R. E., and Lieutenant Harman, R. E.

General Walker has since very kindly placed at the writer's disposal some of the results attained; and, as these represent the most complete researches on the subject, a few extracts and abstracts will now be given. The first extract is from a letter from Lieutenant Harman, R. E., to the Surveyor General reporting on the operations for obtaining the discharge of the rivers in Assam. Lieutenant Harman says:—"para 12. A paper has recently been written by————Gordon Esquire, Executive Engineer in charge of the embankments of the Irrawaddy river in Burma, to show that it is much more likely the water of the "Sanpo" river in Thibet flows into the Irrawaddy than into the Brahmaputra. I now give some extracts from his paper, and following them is some further information I can bring to bear on the subject:—

"(a). The Brahmaputra river, below all the feeders which have any claim to be considered as the Sanpo, is very little larger than the Sanpo at its lowest known point.

"(b). According to D'Anville's map, the watershed area of the Sanpo within the plateau, including those of the "Kenpon" and "Tchomtchou," is 185,000 square miles.

"(c). The Sanpo rises at the Miriam-la (pass) 15,500; at 350 miles it reaches "Janglache," 13,500, and becomes navigable; 85 miles lower down is "Shigatze"; below Shigatze for 85 miles to the Chaiksamchori, iron chain bridge, it is unknown.

"(d). About Chaksamchari, Father Giorgi said, the river is spanned by 500 links, each 1 foot long. Mr. Bogle said: the river was as wide as the Thames at "Putney." Mr. Manning said: the river was far from rapid. Pundit Nain Sing said: the river at Chetang (70 miles below Chaksamchari) was about 500 yards wide, the current very sluggish; by measurement he found that at no place was it deeper than 18 feet and the velocity at about 150 feet from the bank was $\frac{2}{3}$ miles per hour, or about 1 foot per second.

"The valley of the river is several miles across; on the left bank there is a bank of sand $1\frac{1}{2}$ miles wide covered during the rains.

(e). " D'Anville's map shews the Sanpo for 4° of longitude east of " Lhasa," this carries it to the meridian of the water-parting between the Brahmaputra and the Irrawaddy.

(f). " The Sanpo is not likely to rise over 15 feet on account of its steep slope; this with a high flood velocity of 7·5 feet per second, would give a discharge of 750,000 cubic feet per second."

(13.) " In the year 1876, I was directed by the Superintendent, Great Trigonometrical Survey of India, to write a narrative and construct a chart to illustrate the travel of a native explorer (in the service of the Great Trigonometrical Survey of India,) who had just returned from Thibet. From that narrative I extract the following passages :—

He journeyed from Darjeeling by the " Teesta " valley to the 'Kangra'—'Lama' pass on the north frontier of Sikhim; from the pass he went by 'Khambajong,' to Shigatze, a route over new ground. In November 1875 he left Shigatze and went along the right bank of the Sanpo as far as 'Jagsa' a distance of 45 miles over new ground. He could not give a good account of the size of the Sanpo between Shigatze and Jagsa; he said that in places it runs in two or three channels, and sometimes opens out into large expanses of water, the flow hardly perceptible; the banks of the river are shelving, and the water never rises more than 6 or 7 feet above the dry season level; the bed of the river is stony in places, the stones small; there are many extensive spits of sand; the current is very slow, at no place is it at all rapid; at times the country gets flooded, especially about the village of 'Tuktukha' but the water does not go far inland; the margin of the river for a width of 20 to 60 paces was bound in ice; the river, it is said, never freezes over entirely; a waterway always remains; there is an organized passenger traffic down steam from Shigatze to Jagsa throughout the year. The boats are oblong frames of wood, covered with leather, and can be carried by one man.

" 'From Shigatze to Jagsa, a plain of 3 to 5 miles in width stretches from the left bank of the river to the foot of a range of rounded hills, rising to about 1000 feet above the plain. This range falls into the river opposite Jagsa. On the right bank the plain is extensive, the bounding hills low and rounded.

" 'A range of hills capped with snow, falls into the right bank at 3 miles east of Jagsa; thence it is said there is no path along the right bank, and the river is full of great rapids. It is certain there is no boat traffic between Jagsa and the Chaksamchari bridge, 40 miles lower down. " From Jagsa the explorer went south west to 'Yarchi' (a new route) and thence by the 'Yamdakchu' Lake over the 'Khamba-la' (pass) to the 'Sanpo' at a place 5 miles east of 'Jama' village. He thence followed the right bank for 50 miles to 'Chetang' (the greater part of the route over new ground. The country bordering the river is very similar to that (already described) between Shigatze and Jagsa. " At Chetang low hills come down to the right bank of the river: the hills bordering the plain on the left bank are low. There is boat traffic between the Chaksamchari bridge and Chetang.

" 'The river bends away in about a north-east direction, flowing in a wide valley to the horizon which is barred across by a snowy range, apparently a great distance off. " The road continues on along the right bank of the Sanpo to 'Chari.' Turbulent wild tribes are found near Chari. A 'Ladakhi' trader just returned from Chari told the explorer that it was a considerable place, distant 15 marches to the east; the road was along the right bank of the river and fairly easy. At Chari [Chari (?) of the Lama survey] the river turns southwards, and passing through a wild country enters lands ruled by English." This accords with the generally received opinion that the Sanpo enters Assam as the Dihong river. Chari, I think, might be estimated as being at not over 8000 feet above sea-level; and where the Dihong river issues from the hills, it is at nearly 500 feet; the distance in a bee-line from Chetang to this place on

the Dihong is 250 miles; from Chari, let us say only 150 miles: then the mean fall per mile from Chari would be under 50 feet, which is not very high for rivers in the Himalayas. "In the month of January 1877, I took the explorer with me to the Dihong river and he said he thought it was much larger than the Sanpo at Chetang.

"The tribes known as 'Bor Abars,' inhabiting the hills about the Dihong, trade directly with the Thibetans (whom they call 'Lamas'). The Bor Abars assert the Dihong to come from the west, and to be an off-shoot from the great 'Sri-Lohit,' which flows on to the east. The explorer gave the following account of the weather during his stay at Shigatze. No rain in May, but sky very cloudy; about the middle of June the rains set in, and a good deal fell in July and August—the prevailing winds from the east; in September only a little rain, sky very cloudy; in October no rain, very strong cold winds from the east."

"I have met at Darjeeling many Thibetans who have crossed the Sanpo; they all agree that the river rises from 7 to 8 feet but is never rapid enough to stop boat traffic. The river may rise 15 feet at Chaksamchari, but boats can always pass under the bridge. Some say the width of water at the bridge is 80 paces; others estimate 120. By measurement I find that the area drained by the Sanpo to the west of longitude 92° that is, east of Chetang is 78,000 square miles. As a private opinion, merely what I think, I would put down the dry season discharge of the Sanpo at Chetang as under 15,000 cubic feet per second and the high flood discharge at under 250,000 cubic feet.

"14. I have drawn a map (attached) to shew all the well-determined geography of this part of Asia so far as I know. On a like skeleton of lines of latitude and longitude I have sketched in the map of the Lama survey (D'Anville's). This shows the "Sanpo" to fall into the "Subansiri" river; as for the rest of the rivers of D'Anville's map, I cannot fit them into my map by any arrangement.

"Mr. Gordon lays great stress upon the general accuracy of the Lama survey as shown in D'Anville's atlas on account of the proved general agreement between it and the results of recent explorations. But the country to the east of longitude 95°, especially that to west of Bathang, is of a very different physical character to the open lands of Thibet, and I think too much reliance should not be placed on the survey.

"15. As the Assam valley principal triangulation worked up the Brahmaputra river, a survey peak of low elevation (13,000) was observed in a direction a little E. of N.—from Dibrugarh. To the east of that peak as far as the snows to east of the Dihong river, no distant peaks were visible. As the triangulation went on towards Sadiya and passed Sadiya, no high peak could be seen, although the series was a long way from the outer or bounding range ("Riya" range), and that range not a high one. The conclusion was that behind the first high range there was a large expanse of country without points of high elevation, and through it the Dihong river flowed. The hill tribes said such was the case and it is known that, after passing the great rapids on the Dihong the river can be navigated up for some days.

"In 1877 when at work on this 'Yellu' peak (7,700), in the Miri hills, close to the Subansiri river, it was seen that the long line of ridge separating the basins of the Subansiri and Dihong in a N.E., direction, and about 45 miles distant, was in many places very low, two points standing up at least 2000 feet above the ridge, have been proved to be only 5,000 feet. Beyond this ridge there seemed to stretch away a great expanse of low hills. The great ridge of snow to east of the Dihong breaks down suddenly into those low hills.

"While at work in the Miri hills, we were unlucky in not being able to secure all the snowy range between longitudes 95° and 93½°. The Government of India, a short while before we should have taken the field disapproved of any

survey work being done to the north of the Brahmaputra, of course, it took time to have the matter reconsidered, and when sanction was given the season for observing distant peaks was advanced ; thus the snow work is incomplete, and the what-looked-like gaps is the snows at E. and F. were only seen once. The expected gap at C-D., was not noticed, *i e*, it did not appear to exist; but as both Pundit Nain Sing and the explorer whose travels I have mentioned in paragraph 13 were clearly informed that the Sickung Sanpo river flows into Assam, I have connected that river with the Subansiri. In January and February 1878, one hill peak was occupied for 20 days. No view of the snowy range (only 50 miles off) was obtained.

"The following fact was determined: the country to north of latitude 28° must supply 8,000 to 9,000 cubic feet of water per second to the Subansiri at the minimum level of the year. The limits I have assumed for the basin of the Subansiri above latitude 28° are shewn by red dots on my map, and the area is 4,500 square miles. The high flood discharge of the Subansiri I take to be 240,000 cubic feet, derived from about 7,000 miles of country; but the rainfall of that district would, if measured, I believe, be found enormous.

"These observations on the Subansiri dispose me to shift the Sanpo of the Lama survey a degree further to the east, it would then flow down the Dihong river, whose minimum discharge is 55,000 cubic feet and maximum about 450,000. From what I have written on the Sanpo, it is on the Dibong I would build my hope, and I would consider it of sufficient capacity to have received the Sanpo.

"If such is not the case, then it would seem that the Sanpo must take an immense bend to the north, in order to give sufficient drainage area to the Dihong. I would mention that this year Captain Woodthorpe R. E., determined all but a mere trifle of the drainage area of the Dibong river.

"16. While at work in Assam, I endeavoured to start explorations to the north of valley of the Brahmaputra, and my first object was to trace up the Dihong river. After a year's training, two "Khamptis" became skilful enough to be started off; they made two attempts at the Dihong and failed each time. Besides the Khamptis, I know of no men in Assam fitted in any way for such work.

"When in the Subansiri hills, we could never get even tolerable accounts of distant villages. No village goes beyond the boundaries of its next neighbours. The villages within 25 miles of the plains prevent the back people from passing by so as to trade with the plains on their own account.

"Exactly the same state prevails on the Dihong, only the exclusiveness is more rigidly enforced; no stranger is permitted to enter the hills, and none ever go there.

"The hill tribes are a very low, coarse, and unintelligent lot of barbarians. I think it not possible for a single or a few men to pass through their hills. In February 1877 was held the annual fair at Sadiya, when the hill tribes of "Mishmis," "Sinfos," "Khamptis" came in numbers to trade. The darogah of police ("Laman") at Sadiya has considerable influence with these people. By previous arrangement, I sent him the native explorer (vide paragraph 13), but it was not found possible for the man to be despatched. Since I have been in Darjeeling, an intelligent and well educated Bhootea, a "Lama," and young, has been trained to the work of exploration. He has been sent to Chetang to trace the Sanpo down as far as he can; he has been gone three months, and should return in May 1879. I am as sanguine of his success as he is himself.

"17. The survey party in the Subansiri valley were restricted in the extent of their explorations. It is our opinion that a party could travel with safety over a great extent of country, beyond where we left off work, and the results obtained would be most valuable."

The above extract gives most valuable information such as is nowhere else accessible, and represents the very latest views of a competent professional engineer whose researches were made with the special end of elucidating the questions raised, not only by the writer, but by the various enquirers who have been compelled to doubt the conclusions assumed to be held by modern geographers on the subject. The diversity of opinion on these points has been generally indicated in the concluding sections of Part I of this Report, where it was mentioned that Major Godwin Austen, R. E., a Superintendent of the Survey of India who had for some years been working in that neighbourhood, read a paper before the British Association in 1877, contending that the Subansiri was more probably the recipient of the Sanpo than the Dihong. Major General Thuillier, also, had brought forward views renewing the claims of the Bramakund branch to be the true Sanpo ; and had hazarded the opinion that possibly the Dibong might be the favored river.

Operations of the Survey Department in Assam in 1877-78.

(b). General Walker thus describes the operations of the Survey Department in Assam during 1877-78 (i) "The principal object of the operations during the present year has been to extend the triangulation of the region between the Subansiri and Dihong rivers as far as practicable, with a view to ascertaining which of these two affluents of the Brahmaputra river is most probably the continuation of the Sanpo river of Thibet—the celebrated river, which, after having long been supposed to be the principal source of the Irrawaddy, has of late years been conjectured to be that of the Brahmaputra instead. As there was reason to fear that political difficulties might intervene to prevent the Survey Officers from proceeding a sufficient distance beyond the frontier to settle this much mooted point by actual survey across the hills and up the Sanpo river, Lieutenant Harman was directed to measure the discharges of the Subansiri, the Dihong, the Dibong and the Bramakund rivers, in order that by ascertaining the volume of water in each river, additional evidence might be brought to bear on this interesting and important geographical problem."

"Under instructions from the late Surveyor General, Captain Woodthorpe accompanied Lieutenant Harman to the Miri hills. In the Subansiri basin the party sketched an area of about 1500 square miles of country and obtained a fair knowledge of about 400 square miles beyond. This included a portion of the Dihong river, higher up than any portion hitherto surveyed, but not sufficiently high to show whether the river is the continuation of the Sanpo or not. After this, the party separated, Captain Woodthorpe proceeding to make a survey of the Mishmi Hills, while Lieutenant Harman commenced the observations for the river discharges as follows :—

"First, the Subansiri river, at Pathalipaan village, 3 miles west of of the Gogah-muk Ferry, and about 10 miles below the entrance of the river into the plains ; secondly, the Brahmaputra river, on a line due north of, and 3 miles distant from, Dibrugarh, and below the junction of the Dihong and the Dibong rivers ; thirdly the united stream of the Dihong and the Dibong rivers at one mile below their junction and the same distance above the junction with the Brahmaputra ; fourthly, the Dibong river, at one mile above its junction with the Dihong, and half a mile below the junction of the Sensri river with it ; fifthly, the Brahmaputra river ; about 9 miles above Sadiya and half a mile below the junction of the united stream of the Tengapani and Noa Dihing rivers with it ; and sixthly, the united stream of the Tengapani and Noa Dihing rivers, at about 200 yards below their junction.

"44. As regards the main question, whether the Sanpo river enters the Brahmaputra river or the Irrawaddy, the evidence is not yet conclusive. The claims of the Irrawaddy to be the recipient of the Sanpo have recently been put forward, with great skill, by Mr. Gordon, Civil Engineer of the Department of Public Works in Burma. Mr. Gordon's reasons are based mainly on

(i). General report on the operations of the Survey of India during 1877-78, page 16.

the circumstance that the known volume of the great river, at various points of its course, in Upper Burma more particularly, is inconsistent with the sources of the river being so near at hand as in the hill ranges to the east of Assam, where they have been relegated ever since geographers arrived at the conclusion that the Sanpo was not the source of the Irrawaddy. Now, though in this the geographers are very probably correct, they are as probably wrong in having placed the source of the Irrawaddy so low down. Lieutenant Harman has pointed out that there is an ample area of *terra incognita*, in the regions to the north east and east of Lhasa, to furnish a river for the Irrawaddy. And on Standford's library map of Asia a large river called the Sok, to the north, and the Gugbo lower down, and closely following the meridian of 96°—is shown as rising several hundred miles to the north of Assam, and eventually entering the Dibong branch of the Brahmaputra. This river may very possibly be the parent stream of the Irrawaddy, it certainly does not enter the Dibong, for Captain Woodthorpe's recent survey of the valley of that river, see paragraph 51,shows conclusively that the sources are situated at a comparatively short distance beyond the Assam frontier."

(c). Captain Woodthorpe's report on his survey contains the following notes:—*(b)* on the 11th January we returned to Bini via Dicho, picking up Lieutenant Harman there. (7). Our arrangements were completed by the 23rd January, and we started up the Subansiri, taking two boats with us. The banks are steep and rocky in some parts, bouldering in others, and difficult in all for our laden coolies, but they managed to get along fairly well. The rapids are numerous and dangerous, and much care and skill were needed to get the boats safely over them, indeed, at one we lost a boat on the second day. We arrived on the 9th February at a village called Marnia. From this village we had hoped to have been able to make a trip across the range above, from the other side of which we ought to have obtained an excellent view of the country between Marnia and the snows. Fate however, was once more against us; rain poured in torrents for most of the time we were there and even in the few intervals when the rain was not falling heavy fog shut out the view yet effectually. We remained three days in the vain hope of a break. (9). As before mentioned, we were prevented by the strict orders of Government from following up the exploration of the Subansiri as far as was necessary to declare positively that the Sanpo does not find its way through the snows into that river. That the Subansiri rises behind the high snowy peaks seen from Tezpore and the Brahmaputra, I think very likely from its size and velocity; but its volume is only one-fourth of that of the Dibong, which we consider most likely to be the outlet of the Sanpo. If the Sanpo does not add its waters to the Dihong, it must either fall into the Subansiri, or passing along to the east, fall into one of the large rivers flowing through China. Neither of these suppositions commends itself to us; for, in the first place, we do not consider the Subansiri large enough to contain the Sanpo; and, in the second place, if it did flow into China, it would restrict the drainage of the Dihong to an absurdly small area. Mere theories on geographical questions, however apparently well based on observation, have so often proved false, that it will only be by a much more extended exploration than we were able to make that the much vexed question of the course of the Sanpo, will be finally set at rest. The actual results of our work are that we have accnrately defined 1,500 square miles of country on the scale of two miles to the inch, and obtained a fair knowledge of about 400 square miles on a smaller scale of country besides that actually visited and mapped on the larger scale. (10). The Subansiri* is a noble river in the hills, and the gorges through which it emerges into the plains are singularly fine; the banks formed of precipitious masses of rock enclosing deep pools in which measurements give a depth of 70 and 80 feet; the river is about 70 yards broad at Ganditula, and flows with great velocity. I have already mentioned the rapids

Captain Woodthorpe R. E's., notes on the surveys of the Subansiri and Dibong river basins.

* Called also "Hubanhire" by the Assamese.

which increase in number and violence up to Sidang Mukh, beyond which it is navigable for only a few miles. During the cold season Lieutenant Harman calculates that at least 9,000 cubic feet per second of its volume are derived from the country lying north of latitude 28″. We made a fresh start on the 15th March. (18). The Dibong is a fine river, divided up in the plains into a regular network of channels through all of which it flows noisily, and with great velocity, difficult rapids occurring in quick succession. These retarded the progress of the boats considerably, and as we could not leave them, our marches were necessarily short. Heavy storms, moreover, caused the river to rise several feet, thus increasing our difficulties. On the 21st we arrived at Nyain Ghat, the principal crossing of the Mishmis and Abors. It is just at the entrance to the hills, and the river is only navigable for about 3 miles further up, beyond which the rapids become very violent. (19) On the 25th March I entered the hills. I visited the hill on the 28th to see if I could take a portion of my camp up there and found plenty of snow on the top, and a small spring of water not far from the summit. I returned to camp at night, and it began to rain at 8 P. M., and went on for 26 hours without a moment's cessation, quite precluding all idea of moving camp. I had sent back coolies to Nyain Ghat to bring up a week's supplies, and I was fearful lest this flood should hinder their return, as I knew several bridges must have been swept away, and we could hear the Dibong roaring along in its narrow valley 5,000 feet below us. I afterwards ascertained that it actually rose 16 feet in those 24 hours. Again we had cloudy, showery weather, and I scarcely got a glimpse of the country around till the 2nd April. (21) We were detained at Chini for 3 days by incessant rain and heavy hailstorms, and while here we were presented with a mithan by the head man; it was promptly killed, and kept the camp in fresh meat for some time. On the 7th we made a start eastward, and reached Nipu village a little before night fall. On the 9th accompanied by Kalude, Lakho, Chini, &c., we commenced the return journey in a fearful downpour of rain. (25) The results of our work in the Mishmi Hills are (1) a fairly accurate knowledge of the sources of the Dibong and the course of its main stream in the hills; (2) an accurate knowledge of its course in the plains, and of about 1,000 square miles of the hills bordering it; (3) an approximate knowledge of an additional 1,100 square miles in the hills."

Lieutenant Harman R. E's., measurements of the Brahmaputra and its tributaries.

(d). The measurements for discharge made by Lieutenant Harman are given in the accompanying table, together with the results estimated by him for lowest water, for ordinary high flood, and for extreme high flood. The whole of the measurements were made between the 24th February and the 6th April 1878 when the rivers are at, or a little above the lowest water of the year. The bottoms of all the rivers measured were of coarse heavy sand, excepting a short stretch of big pebbles in the bed of the combined Dihong and Dibong rivers. The instruments for measuring the velocities were discs of wood 3 inches in diameter and $\frac{1}{4}$ inch thick, marked by a little mass of cotton wool thrown over a peg standing upright in the centre of the disc. Also tin tubes, 1 inch in diameter, closed at one end, varying in length from 2 to 10 feet, containing enough water to sink the tubes, so that only 3 or 4 inches of them remained above water. In the mouth of the tube was a cork and some cotton wool for a marker. The velocities of these were observed when carried by the current across parallel sections marked out on the river. The results are as follows:—

Date of Measurement.	Height above low water.	Actual Measurement.			Low Water.		Ordinary Flood.			Extreme Flood.		
		Width	Area.	Discharge.	Area.	Discharge	Rise.	Area.	Discharge.	Rise.	Area.	Discharge.
		Ft.	S. Ft.	C. Ft. per second.	S. Ft.	C. Ft per second.	Ft.	S. Ft.	C. Ft. per second.	Ft.	S. Ft.	C. Ft. per second.
1878			Subansiri River.									
February 25-28th	0	1,077	9,637	16,945			16	35,750	170,000	22	48,750	240,000
			United Dihong and Dibong.									
March 24—27th	3	2,295	25,105	110,011	18,833	82,652	15	84,000	485,000	20	98,000	567,000
				Dibong alone.								
27th	5	948	10,992	47,383	6,375	27,202	15	23,692	122,483	18	27,700	144,000
				Dihong alone, estimated quantities.								
						55,000			362,000			423,000
			Brahmaputra above Sadiya.									
April 2-5th	3	2,981	16,396	66,251	8,228	33,832	16	53,017	293,000	18	59,000	326,000
			Brahmaputra at Dibrugarh.									
March 4-18th	0	1,905	24,477	116,115			16	164,000	830,000		208,000	1,100,000

Both the flood discharges and the lowest water discharges when these were not actually measured are merely probable values. From the methods employed it is probable that the low water discharges are somewhat too high, and the extreme flood ones somewhat too low ; but as the same process was used for all, and they were directly deduced from the actual measurements they must be accepted as showing truly the comparitive discharges for ordinary and for high floods.

Remarks on the foregoing.

(e). Captain Woodthorpe's notes on the surveys prove that extremely heavy rain was falling in the hills during Febuary, March and April, that is, throughout the whole time the measurements were being made, and it is more than likely that in years of drought or on other occasions all the rivers measured would show much smaller discharges than those above estimated. This, however, is a matter of minor interest, as the principal question concerns the relation of the flood discharges to the water-sheds.

There can be little or no question that somewhat similar rates of discharge from the water-shed to the river should obtain between all the affluents of the upper Brahmaputra whose gathering grounds are found on the outer flanks of the Himalayas and in northern Assam. In this Report it was stated that Wilcox's map gave about 2,500 square miles as the water-shed of the Dibong. This result has been confirmed by Captain Woodthorpe's survey. The Brahmaputra above Sadiya was estimated to have a water-shed of about 7,000 square miles. Lieutenant Harman estimates the water-shed of the Subansiri, from his survey, to be about 7,000 square miles. The respective high flood discharges of the three rivers as estimated by Lieutenant Harman are 144,000, 326,000 and 240,000 cubic feet per second, which give the rate of supply per

square mile as nearly 58 cubic feet per second for the Dibong ; 47 cubic feet for the Brahmaputra, and 35 feet for the Subansiri. The water-shed of the Dihong lies between those of the Dibong and Bramakund on the one hand and the Subansiri on the other. It is probable therefore that its rate of supply lies intermediate with these also. Taken at 40 cubic feet per second for each mile, it would only require 10,600 square miles of such water-shed to yield the large supply of the Dibong.

The surveys of Captain Woodthorpe and Lieutenant Harman dispose finally of the claims of the Bramakund, of the Dibong and of the Subansiri to be the continuation of the Sanpo. Both these officers conclude that if the Sanpo does reach the Brahmaputra at all, it must do so through the Dihong. Captain Woodthorpe considers that if it does not flow through this river "it would restrict the drainage of the Dibong to an absurdly small area." Lieutenant Harman says :—"From what I have written on the Sanpo it is on the Dibong I would build my hope, and I would consider it of sufficient capicity to have received the Sanpo. If such is not the case then it would seem that the Sanpo must take an immense bend to the north, in order to give sufficient drainage area to the Sanpo." Incidently, in para 16, he mentions that a young Lama has been trained and sent to trace the Sanpo down as far as he can. This Lama has now returned after following the river to a point where it is supposed to be opposite to the debouchment of the Dihong into the plains. The following account of his exploration is taken from the London Times of the end of August 1879 (just received) which is a notice of a paper read before the British Association in 1879.

The Sanpo exploration of Lieut. Harman's trained Lama.

(f). "Mr. C. Black read a paper on the upper course of the Sanpo or Brahmaputra river with special reference to an important exploration recently made by a native Surveyor, attached to the Indian Survey Department. After giving a general description of the geography of the upper portion of the Sanpo as derived from Messrs. Bogle, Manning, and recent travellers, Mr. Black proceeded to describe the new survey, which commenced east of Chetang, a village in eastern Thibet. Previous explorers had reported that the course of the river east of that point was first east and then south-east. This proved to be only partly true, as the Sanpo proved to make a huge bend to the northward being entering on its south-eastern course towards Assam. Various towns and monasteries lay dotted about the valley, some of which were curiously identified by the author with names on d'Anville's map, prepared in the early part of last century. This bend was previously quite unknown, and now leaves room for a northern feeder of the Subansiri, thus accounting satisfactorily for its large bulk, a fact which hitherto had proved somewhat of a puzzle to geographers. Mr. Black concluded by citing some interesting corroborations of this new discovery afforded by information collected by the Abbe Desgodins and by Lieutenant Harman's recent measurements of the discharges of the large rivers of Assam"

Further remarks on the new evidence.

(g). The details of this paper are not available, but the account given of the Sanpo fits in very curiously with the requirements of Captain Woodthorpe and Lieutenant Harman, should it eventually be proved that the Sanpo does not enter any of the Assamese rivers. These officers have satisfactorily determined that the Subansiri and the Dibong cannot receive the Sanpo. They have also, from actual surveys proved that the Dihong occupies a large region lying to the north of the Subansiri watershed, and between this and the Sanpo. Mr. Black's surmise that the watershed added to the Brahmaputra tributary by the immense northern bend of the Sanpo belongs to the Subansiri is therefore unfounded. It must belong to the Dihong alone. The information already accessible shows that the Dihong has very little short of 10,000 square miles of watershed on the southern slopes of the Himalayas ; and the additional area now proved to exist by the last exploration amply suffices to provide the total discharge of that river as estimated by Lieutenant Harman.

It is quite impossible that it can contain also the discharge of a river like the Sanpo, even taking this at the low estimate surmised by him. It is more than probable that this estimate is very much less than the truth. Even with an eight foot rise of flood, the Sanpo must, where crossed by the Pundit, have a cross sectional area of at least 58,000 square feet. This, with a mean velocity of 6 feet per second gives a discharge of almost 350,000 cubic feet of water per second. It is more than likely that in extreme flood it will be higher, and be considerably more than the maximum discharge estimated for the Dihong.

In the extracts now given, we have, as far as possible in the words of the writers themselves, the final results of the latest researches on the connection of the Sanpo with the Assamese rivers. No criticism on them is at present offered, as they all fit in, like the pieces of a dissecting map, to the one conclusion, that the Sanpo has no connection whatever with the Brahmaputra. That this opinion was also shared by the only living geographer of eminence, who, besides the officers of the Survey of India, has had personal contact with the problem, may be learned from the following extract from Mr. James Fergusson's paper on recent changes in the Delta of the Ganges, where, after mentioning that he had resided for five years on one of the most active of the Bengal rivers, and after making a special study of the delta of the united Ganges and Brahmaputra he remarks "though the length of the course of the Brahmaputra is only one half that of the Ganges (for it is not clear that it has any connection with the Sanpo of Thibet) still the two rivers are quite equal in volume." Here is the unprejudiced opinion of a most competent Judge, directly adverse to that put forward as being shared in " by all modern geographers."

The writer has been unable to find writings of any geographer of recognized eminence, who, from personal acquaintance with the subject, or who, following out a course of argument founded on facts different from those brought forward, has endeavoured to place the claims of the Brahmaputra to be a continuation of the Sanpo on a scientific basis. There is, in a few writers, who on other grounds are high authorities, much assertion that the Sanpo and Brahmaputra are the one river; but it is difficult to see how this opinion, which, at present, is a merely speculative one, can be sustained, unless the whole of the data we possess both as to the size and the probable discharge of the Irrawaddy and its need of large gathering grounds, to the size and discharge of each Assam influent of the Brahmaputra and the sufficiency of its watershed, and on the size and probable discharge of the Sanpo and its exact fitting in with the requirements of the Irrawaddy are utterly and entirely wrong. It is just possible that further research may shew this to be so; but the balance of evidence is at present against it.

(h). The following extracts are made from the Survey Report for 1877-78 and are taken from a Report on the Trans-Himalayan operations (Trigonometrical) conducted by Mr. E. C. Ryall in Hundes, part of Chinese Thibet, during 1877.

Mr. Ryall's notes on the high peaks, the snow line and the winds in Hundes, part of Western Thibet.

" Hundes (Nári Khorsum) is that portion of Thibet, under the Government of China, which occupies the upper basins of the Sutlej and the head waters of Karnali river."

" From my stations in Hundes 38 snowy peaks were laid down across the Sutlej, some were fixed by single deductions only, but there cannot be much doubt as to them, for their proximity to those determined by double deductions materially helped towards their identification. Among the snowy peaks laid down, the most notable in appearance is Gurla Mandhata also called Nimi Naingil. Gurla Mandhata lies to the N. E. border of the Purang district of Hundes, and its elevation above sea level is 25,360 feet; another notable peak of Kailas, but not nearly so lofty, being only 21,850 feet, lies due north of Gurla, distance 43 miles. Between the two above named mountains, are the celebrated lakes of Manasarowar, Tso Mapham or Cho Mapang, and Tso Lanak or Lang Cho. Owing

to its immense bulk and height, 3,000 feet above any within a radius of 40 miles, it (Kailas) is perhaps the most impressive sight in the whole of the Himalayas, the celebrated mountain of Nanga Parbat N.W. of Kashmir alone excepted, which is over 26,000 feet high and stands prominently conspicuous in a command of about 10,000 feet over all peaks and ridges within a radius of about 40 miles. Of the other snowy peaks laid down in Hundes, it can only be said that they are not remarkable in appearance. They seldom tower over the average height of the ridges by more than 1,000 feet."

"When I first caught sight of this northern range on 8th June 1877, there was a very fair quantity of snow on it, but at the end of 20 days, very little remained. A few peaks here and there had snow on them to about 3 or 400 feet below their summits. Judging from the fact that the amount of the fall of snow during 1877 was exceptionally great, and that, 20 days' exposure, shortly after the inclement weather gave over, was enough to melt it up to nearly 20,000 feet ; I am of opinion that the snow line is rarely, in any part of Hundes, and even among the mountains of Monyul about Rudok and Gartok, under 20,000 feet, and in some places as high as 21,000 feet. The plains, the low ridges on them and the mountains separating these from the British dominion are chiefly composed of clay-slate and fossiliferous limestone."

"While employed on my work of triangulation, I remarked a singular fact with regard to the different velocities of wind at various elevations. Over 18,500 feet, I found the usual prevailing southerly wind to diminish in force. And at 19,500 feet there was a marked diminution in speed. The temperature, mid—June 2 P. M. generally falls below 30° F, and at one station 19,550 feet, it fell to 25° at that time of day. The strongest currents of wind, experienced by me in Hundes and the Bhot districts of British Kumaun and Garhwal, were at elevations ranging between 15,000 and 18,000 feet. In fact it blows furiously at these elevations, where the current begins to flow an hour after sunrise, acquiring its greatest speed, about 35 miles an hour by 2 P. M., and continues unabated till sunset, when it gradually diminishes and then subsides long after dark. In the Bhot districts of Kumaun and Garhwal at elevations between 9,000 and 15,000 feet, the wind blows, though not so furiously as at higher elevations, yet at considerable pace. The change in the velocity of the wind at different elevations is doubtless due to interruptions in its general progress, offered by intervening mountain ranges. The greatest opposition is offered by those series of mountain masses which lie considerably south of the main watershed, and which average about 23,000 feet above sea level. These are the Gangotri, Kedarnath, Badrinath Irisal, Nanda Debi, Nanda Kot, Panja Chuli and Nampa groups in Kumaun and the two Garhwals. It has been noticed by other travellers, that the largest peaks in the Himalayas, from Bhutan on the east to Kashmir on the west, occur considerably south of the watershed lines separating Thibet from India. The wind on the passes is very little short of a regular hurricane. Whirlwinds sometimes occur on the passes, but fortunately rarely. They are not uncommon on the plains of Hundes. I heard of a fatal accident caused by one a few years before my visit to the place. This was on the Balchdurra pass. A Bhutia of Tola village in Johar on arriving at the top of the pass, was lifted off the ground, carried away some 100 yards or so, and then dropping, was dashed to pieces. I had always, except at three of my most elevated stations, while on the borders of Hundes and in Hundes itself, to take my observations in a very respectable kind of storm, and this though never ceasing during the day, used to put on occasional spurts in fitful gusts. The only way to get on with the work under the circumstances was to shelter myself and my instruments as much as possible, by putting up a protecting kanat 6 feet high, to keep which in position I had to get 10 or 12 men to stand against it in a slightly inclined position, very frequently I had to re-enforce these by 5 or 6 more. The high wind on the plains of Thibet and the intervening ridges is seldom if ever absent, when at its height, and sometimes it is simply furious, it is very harrassing, rendering travelling against it a most toilsome undertaking. Owing to these high winds, the difficulty of ob-

serving far signals was much increased. The rapid undulations of the currents causing the signals to appear to dance about wildly. * * * The following short description of the road leading through Milaur, would apply almost equally to those of Darma and Byans. This road passes along the sides of a deep and stupendous gorge, over hung mostly by lofty precipices of granite. The road way is a mere series of narrow steps built along the faces of rugged cliffs, and where the side of the cliff is too smooth, the smooth intervals are spanned by narrow planks. Naturally the road is one series of ups and downs sometimes rising to the height of a thousand feet above the river, and at others descending to its bed. The insecurity felt in travelling along such a road is very great. Fatal catastrophies along it are not uncommon. During the rains and the melting of the snow, to insecurity under foot, must be added dangers overhead, from avalanches and mountain slips which bring down with them showers of large rocks."

(k). The following detailed account of the last exploration of the Sanpo has been kindly furnished by Major General Walker (7th November 1879.)

Further information on the last exploration of the Sanpo.

Exploration of the great Sanpo river of Thibet during 1877, in connection with the operations of the Survey of India. By Major General J. T. Walker C. B. R. E., F. R. S.

"The course of this river has been explored by a new explorer N-m-g. for a distance of about 200 miles below the town of Chetang, the lowest point previously fixed. N-m-g. was employed under the immediate instructions of Lieutenant Harman, R. E., who has been writing out his journals and reducing and mapping his observations, but Lieutenant Harman has had his time so fully engrossed by his regular duties in connection with surveys which he is carrying on in and around Darjeeling, that he has been unable as yet to send in the full report of the explorations. The following is therefore to be regarded merely as a provisional account of them."

"N-m-g, was deputed to Chetang, the possition of which had been determined by Pundit Nain Sing in 1875. His instructions were to explore the course of the Sanpo river downwards for as great a distance as he possibly could. Crossing to the north bank of the river he went along it eastwards for a distance of about 30 miles nearly down to the point where it is joined from the north-east by a small river called the Mikchu ; here he had to leave the river, and make a considerable detour, up the Mikchu valley, and over the Lungla pass on the range which forms the eastern boundary of the Lhasa basin, then down the valley in which the Chokorgye monastery is situated half way up and that of Thakpo at its lower end, near the town of Gyatsa Jong on the Sanpo river ; here he again struck the river which had been wending its way through the mountains for a distance of about 20 miles while he had been making a detour of over 50 miles. From Gyatsa Jong onwards he kept to the river, until he reached Gya-la Sindong, beyond which point he could not advance."

"About 30 miles below Gyatsa Jong he crossed over to the right branch of the river near Thakpo Nongjong ; this place is situated near the junction of a river from the south which is said to pass by the town of Tsari, which Lieutenant Harman believes is identical with D'Anville's Chaii.

Up to Gyatsa Jong the course of the Sanpo river is fairly in accordance with the course shewn on Pundit Nain Sing's map of the country which he traversed between Lhasa and Assam, via Tawang; Nain Sing had seen the course of the river for a distance of about 30 miles below Chetang, and he had been informed that from that point onward it flows in a south easterly direction into Assam. We now find that it does flow in a south easterly direction, but only for a short distance beyond Gyatsa Jong, after which its course is due east for some 50 miles and then north east for about 80 miles. The river reaches its

most northern point near the intersection of the meridian of 94° with the parallel of 30,° about 12 miles to the north east of a place which the explorer calls Chamkar, and which Lieutenant Harman identifies with d'Anvilles' Tchamca."

After attaining its most northern point the river turns due south east, reaching Gya-la Sindong in 15 miles, beyond which place N-m-g, was not able to follow it. There, however, he saw that it flowed on for a great distance passing through a considerable opening in the mountain ranges to the west of a high peak called Jungla, of which the bearing was 130°. Beyond this opening the river was said to pass through a country inhabited by savages into a land ruled by the British Government."

" Assuming the position of Gya-la Sindong to have been fairly well determined by the explorer, its direct distance from the highest point hitherto on the Dihong river, in the course of the survey operations in Assam, is only about 100 miles. The height of Gya-la Sindong was found by the explorer to be 8,000 feet showing that the river had fallen about 3,500 feet in 200 miles of distance from Chetang and leaving a descent of 7,000 feet for the distance of 160 miles down to the junction of the Dihong river, with the Brahmaputra ; this does not give an excessive slope compared with other Himalayan rivers."

Discussion of the result attained.

(1.) It may not be out of place to notice the results now acquired with the interpretation given to them by Lieutenant Harman and those who advocate the identity of the Sanpo with the Dihong. The sketch map annexed to General Walker's paper in the Asiatic Society's Journal allots all the territory newly discovered as lying between the Brahmaputra and Sanpo valleys to the Subansiri ; the Sanpo, which is shown as surveyed to 94° 12′ 8″ long., and, after having almost touched 30° N lat., is left in 29°·43′, is joined by dotted lines to the Dihong, which has been traced to 94° 52′ 8″ long., and 28°·30′ N lat. The river is thus made to describe 1°13′ of latitude in 0°·40′ of longitude. This junction of the Sanpo with the Dihong, and the drainage of the new territory to the Subansiri are entirely conjectural, and are contrary to the evidence available.

The principal fact now established on indisputable grounds is that the course of the Sanpo lies no less than one degree to the north of the route hitherto ascribed to it, and there is thus added for every degree of longitude one square degree of about 4,250 square miles in extent to the drainage area of the Brahmaputra, through its Subansiri or its Dihong tributaries. It is estimated that not less than 10,000 square miles is thus added to the watersheds of these two tributaries.

It has been finally established that neither the Bramahkund nor the Dibong branches can receive any of this new drainage. Their areas are known and their discharges. It is thus important to determine whether the Subansiri can be entitled to claim the whole of the new watershed.

Firstly, we have Wilcox's testimony as to the Subansiri. He learned that it was divided above into three branches. It is called by the Miri tribes who occupy its valley the Kamla, and the principal branch rises in the north or north-west. He found the discharge at its mouth 16,000 cubic feet per second. It was impracticable for boat traffic through rapids in about 22 miles due north from its mouth.

Lieutenant Harman with Captain Woodthorpe made further explorations in 1877, connecting the peaks of the boundary ranges with the trigonometrical survey. The former took angles from two peaks (Yello 7466 and Pidi 6,327 feet) on the outer range on the right bank of the Subansiri, just above the Brahmaputra plains. From the Yello Lieut. Harman saw the long line of ridge separating the Subansiri and Dihong basins in a N. E. direction, about 45 miles distant, and generally low. Beyond this ridge there seemed to stretch away a great expanse of low hills. It was probable that behind the first high range there was a large expanse of country without points of high elevation, through which the Dihong flowed.

Lieutenant Harman states " we were unlucky is not being able to secure all the snow range between longitude 93° and 94½ the season for observing distant peaks was advanced ; thus the snow work was incomplete, and the what-looked-like-gaps in the snows at E. and F were only seen once. The expected gap at C. D. was not noticed, *i. e.*, it did not appear to exist." In Lieut. Harman's sketch map the Subansiri tributaries are not carried north of the boundary ridge ; but in the sketch map now issued with the latest quoted notes, two large branches of the Subansiri are carried through the what-looked-like-gaps at E and F to drain the area lying between 28½° and 29½°. In the first sketch the Kamla, or the main branch of the Subansiri is shown as confined to hills east of 92°·50′ and a second branch is joined on to the Sekung Sanpo through the mountain range between C. D ; while in the second map the Kamla branch is taken through C. D. the others as stated above being passed through E and F ; a fourth branch from the north east, which was mostly surveyed and had its watershed boundary determined by the party, being also shown.

There is thus a somewhat arbitrary mode of treatment shown in the arrangement of these branches of the Subansiri, for which no adequate ground has been given. The sole justification offered for bringing first the one branch of the Subansiri, and then the other through the mountain ridge at the extreme western end of the valley is that Lieut. Harman was informed that the Sickung Sanpo, the Lopra Cachou of d'Anville, flows into Assam. Of this fact no doubt can remain. But it is not clear why it should not be supposed to be one of the branches of the Dihong, which Wilcox learned from the native Abors, " comes from the west or north-west," a view corroborated by Harman's informants, who stated that it came from the west. This would make the Dihong's western branch coincide with the Lopra Cachou, and its northern one with the Om-chou ; the former skirting the northern edge of the boundary range of the Subansiri, the latter draining all or part of the newly found country south of the Sanpo boundary.

If these conjectural drainage areas and tributaries of the Bramaputra be excluded, the remaining watershed of the Subansiri, contained within the boundary ridge actually determined by Lieut. Harman, measures between 5,000 and 6,000 square miles. The rainfall of that district would, in Lieut. Harman's opinion, if measured, be found enormous. All available knowledge corroborates this view. The region has one of the heaviest rain-falls in the world. We have in the Dibong and Bramakund rivers fairly accurate means of determining the relation of the watershed to the discharge. These have already been found for the Dibong which has a watershed of 2,500 square miles with a discharge of 144,000 and of the Bramakund with water-shed of 7,000 square miles and discharge of 3,26,000 giving rates of 58 and 47 cubic feet per square mile. Now it is highly improbable that the Subansiri rate will be less than these, or than 50 cubic feet per square mile per second. Its high flood discharge is 2,40,000 cubic feet ; and by this rule, the watershed should be not over 5,000 square miles ; thus agreeing with the survey.

Again adding 10,000 square miles, the area of the doubtful watershed to that known to belong to the Subansiri ; we have a ratio of only 18 cubic feet per second coming from each square mile, a result wholly at variance with all that is known of this and the other tributaries.

But give these 10,000 square miles to the Dihong and what results ? It will thus have between 10,000 and 15,000 square miles of watershed of the rainiest region in the world. At the rate of 50 cubic feet per second from each square mile its discharge will be 5,00,000 to 7,50,000 cubic feet, a result largely in excess of the measurements. Probably the mileage rate must be reduced ; but there can assuredly be no need of going to the interior of Thibet to look for new watersheds now that the surveyor N-m-g has demonstrated that such a large extent of Himalayan slopes lies between the Sanpo and the Brahmaputra. It seems impossible any longer to doubt that the Sanpo and the Irrawaddy are one river ; and that the Brahmaputra like the Ganges and the Indus has been wrongly supposed by some geographers to break through the great Himalayan chain.

B

Professor Forchhammer on the identity of the places between Leh and Lhassa, as shown by M. d'Anville and the Pundit Nain Singh.

The eminent philologist, Professor Forchhammer, after devoting nearly 10 years to a comparative study of the Indian languages in the Southern States of North America, has, within the last few years, made a special investigation into the languages of Eastern Asia and Thibet. He is familiar with the Chinese, Mongolian, and Uigure, the language of a people ranging to the north of the Thibetan Plateau, and is acquainted with the Thibetan. At present his studies in Sanscrit, Pali and Burmese have brought him to the neighbourhood of Henzada, where he is engaged under the orders of the Local Government, in drawing up for publication an authentic copy of the Betagat, or burmese scriptures, from several sets of manuscripts. On referring to him the question of the identity of the places shown on d'Anville's map of Thibet, and those mentioned by the Pundit Nain Singh, he very kindly made a thorough and exhaustive analysis of the whole, which is much too large for quotation *in extenso,* but from which he permits the writer to make the following notes :—

After a resumé of the history of the tribes and races of Northern Thibet he says :—" In examining the names of d'Anville's map (which comprises the regions between 74°—120° longitude, and 26°—34° 3′ latitude) with a view to ascertain their etymological character, the various and different nations and tribes, with their respective languages, can to some extent be traced with certainty : pure mongolian names in the north-east ; then Thibeto-mongolian appelations. The other names of d'Anville's map are mongolian corruptions of Thibetan, Sanscrit and Ural-altaic words, written to suit french pronunciation ; thus we find for the Thibetan "; Sámdán Kánjáng," " Samte Kensa ;" for " Tangjung," " Tancong ;" " Kiangri " for Gangri etc.

Kentaisse (d'Anville) is the Mount Kailas of the Pundit ; in thibetan *gang-ti-se.*

(Gang di sri.)

Kyal-chu R (d'Anville) Shyal-chu of the Pundit ($\frac{\text{Shyal to swim}}{\text{chu water}}$)

Professor Forchhammer also gives a number of other names which agree with differently written names on Lassen's map of Ancient India. He says :— " These are but a few examples of names on d'Anville's map which correspond with our present geographical notions, and which are easily identified etymologically." He shows that d'Anville erroneously made the Indus and its tributary rivers flow into the Ganges ; but points out that his map goes into details only as far west as Leh where Nain Singh's journey commenced. " In pursuing the road of the Pundit in d'Anville's map, sufficient evidence will be forthcoming to prove that this courageous explorer has not walked over ground unmeasured before. The names in the Pundit's map are spelled very indifferently ; no distinction is made between the palatal and dental t ; the aspirated and non-aspirated sounds. The Thibetan alphabet has the letters d, d, t, th, t, th (1) : the Pundit uses only d, t, and th. The ch of the explorer's map may be ch, chh, dz, j, ts, ths, sh, z, zh. This circumstance greatly increases the difficulty of the identification and interpretation of the names.

(1.) No type is available to show this distinction marked by the professor.

R. G.

The Professor traces the Pundit's journey as follows:—

Latak (d'Anville) 77° longitude; north 30° latitude, thibetan Ladag (s) (1.) From Ladag the Pundit followed the road to Yarkand; arriving at the foot of the Lankar pass, he turned to the east and south-east; this portion of the journey lying outside of d'Anville's map, the

Dsarin-nor being the northernmost point in it. This name is the thibetan thsaring (chhu), (thsa salt, ring, long), the long salt lake north of

Routon, Rudokh of the Pundit, and is no doubt identical with the Chomo-Gna Laring-cho (Female-narrow-very-long-lake). From this lake to 80° longitude and 33° latitude the explorer journeyed through country which is a blank on d'Anville's map.

Patchon mountains 81° longitude 33° latitude (d'Anville) may be the same name as Beejung. Kiangri (d'Anville) corresponds etymologically and geographically with the Pundits (Thachap) Gangri (82°—83° longitude, N. l. 33°) Ta=horse, pony; chap water Kiangri gangri Snowy hills.

Tchamdson tijac (d'Anville) Tha-chap-cho of the Pundit,
The journey continues north of the Cho-dol and Purang-chaka or the regions in which the

Tchourou-pourou mountains of d'Anville are placed, between 83° and 84° longitude. Nain Singh arrives at the banks of d'Anville's Nacoi river, flowing eastward into the Tashi-Bhup lake, the Tarouc-yom-dson of d'Anville, west of the Thok Daurakpa gold fields [Nain Singh shows the Nacoi river, but does not name it]. To the north of the Nacoi we find on the Pundit's map the names

Cal. M. Gar (che) Thol (Cal M. of d'Anville)?

Tchariu d'Anville, Sara De (Tchari M. d'Anville).

Tarouc-yom-dsón of d'Anville is geographically the Tashi-Bhup of the Pundit; tashi, prosperity, happiness, bhup, to pitch tents, d'Anville's Tarouc-yom-dson has its name from the adjacent gold fields Daurakpa (do=stone and rag-pa=to be laid together, to closely join). To the south of the Tashi-bhup lake we find the

Shyalchi Kang Tang M., and Shyalchu river; on d'Anville's map we meet in the same direction with the Kial-chou M., from which runs a large river to the north into the Tashi-bhup (the Tarouc-yom-dson d'Anville) lake, as indicated by the Pundit.

It must here he remarked that d'Anville's Tarouc-yom-dson lies one degree further east and half a degree further north than the Tashi-bhup of Nain Singh, and that this difference continues to the Tengri-nor. The distance on the Pundit's map between Tashi-bhup and Tengri-nor is exactly 5 degrees longitude and 1° 2″ latitude. On d'Anville's map the distance is little over 4° longitude and 1° latitude. The numerous lakes which are found on the French geographer's map must therefore be compressed in a comparatively smaller compass. The geographical position of the lakes do not exactly correspond with the respective etymological nature of the names. According to longitude and latitude, d'Anville's Chouro-jou-dzon lac would correspond best with Nain Singh's Dangra-yu-cho lake. But etymologically this lake is evidently the Tankinyamso lake of d'Anville; with the Tancong lac, identical with the Tang-jung of the Pundit to the north east.

(1).—Professor Forchhammer gives all the names in the original charracters whether Chinese, Thibetan &c., but as it is improbable that type will be procurable to repeat these, they are not copied out.

R. G.

Dang, dhang in eastern Thibet (Tang on d'Anville's map) means breast, chest, while Rag may simply mean double (as myi-rag double-barrelled); or it might be Ra=horn (having reference to the sinuosity of the lake).

Yum or yom mother, cho or so, a lake. That d'Anville's Tankin-yom-so is identical with the Pundit's Dangri-yum-cho, accrues, besides, from the following circumstances:—

I. To the west of Dangra Yumcho we find the Thok chigi *muli* gold fields, on d'Anville's map a range of mountains or hills called Mhulari Mountains west of Tankin Yamso to the south-east. Mhulari is mulri or ngalri, silver hills or silver mountains; the Pundit's "Muli" is a corruption of mulri or ngulri.

II. North of Dangra Yumcho the Pundit places the lake Tang-jung-cho which is identical with the Tan-cong lake of d'Anville, who, however, situates it to the north-east. Both maps agree in placing them very near to each other and with no mountains between, so that the Pundit's suggestion of these two lakes having once formed but one sheet of water appears plausible from both maps.

III. Though on d'Anville's map we do not find a Ngangziar *Dungche* (if this be not the Ancsai lac of d'Anville) and a *Daru* lake, yet we meet in a geographically corresponding position the Tareou mountains and Tonc-sel M.; the river which flows from Tonkin Yamso lake eastward to the Terkiri lake, bears the name "Tareou Tsan-pou."

IV. The mountain range which terminates on the *Gya-khar-ma-peaks* corresponds geographically and etymologically (?) with d'Anville's Kiamkhana mountains, southeast of Tankin Yamso.

V. On the Pundit's map we find the *Dong-sáng* chu river descending from the northern slopes of the mountain range lying to the north of Nachâng Pontod Lhoma; according to the Pundit this river flows into the Chargut lake. On d'Anville's map we meet with Tondson mountains from which issues a river pursuing first to a little distance a northerly direction (which is also the case with Nain Singh's Dong-sang chu), then it flows eastward, not in the Chargut lake, but into Tan cong yamdso, the Dangra yum cho of Nain Singh. Lho-tod of the Pundit may be etymologically related to "Lop mountains" of d'Anville, so much the more as their geographical position corresponds (tod in Lho-tod means "upper," belonging to the upper part of a valley.)

Kyá-ring lake, or the "long neck" lake, kya, neck and ring, long." If siran (losa) on d'Anville's map is a tibetan word, it may be a mongolian corruption of Kya-ring; losa is tibetan and means "surfaces" and may be a collective name of the numerous lakes lying between Kyaring and Tengri Nor. I have thought of the mongolian word Shira, yellow, but then the compound siran losa remains unexplained. The siran losa river and lake as they are depicted on d'Anville's map, very forcibly suggest the name "long neck" forming as it were a swan's neck to the main body, the Terkiri (Tengra Nor) lake.

Tacsai-raki lake of d'Anville, northward of Siran losa, is geographically the Chikut lake of Nain Singh.

Terkiri Lac of d'Anville is the Tengri Nor or Namcho Chidmo lake of Nain Singh; Terkiri is an Ural-altaic word: tängri in uigorie, tägri in mongolian; it denotes heaven, sky, and also the God or Gods inhabiting these regions

(ratio coeli). North of Pundits Tengri lake we find the Schuma *phurka* mountain (91° longitude) and on d'Anville's map in the same longitude and north of the Schuma phurka M. (according to Nain Singh) is situated the lake Pouka.

The mountain range east of Tengri Nor is called on the Pundit's map Sámdán kang jáng (the northern mount or house of meditation) which corresponds geographically and etymologically with the Samte kensa of d'Anville.

Larkin M. (d'Anville) southeast of Namchidmo is the (Dam) Lorghaun (pass) of the Pundit.

Tancla M. (d'Anville) the (Ninjing) thang lá M. of Nain Singh.

Dam or *Tama* (d'Anville) is the Dam chu of the Pundit.

Lhasa-Lasa.

C

(a.) Extract from Report to accompany Financial Statement of the Irrawaddy Embankment Works.

DATED HENZADA 6TH JULY 1870.

27. *Future progress.*—That the whole of the cultivable land thrown open will be speedily taken up, there is reason to believe. There are 93,000 square miles of land in British Burma, of which only 3,000 are yet cultivated, and the population is on an average only 26 to the square mile. It will be contrary to the received opinion, and it may appear paradoxical to state that the true want of Burma is land and not population; that the latter is increasing faster than provision has been made for it, and that the great evil to be feared just now is overpopulation. Yet on examining the returns, the statement may be thought less absurd than it at first sight appears. I would ask permission to offer a few paragraphs on this matter, which, though foreign to the engineering part of the subject, is still closely connected with the question of the necessity of the embankments. The remarks offered will be few, and are intended only to indicate and suggest some points which may be found worthy of notice.

28. *Table of population.*—A table is given of the cultivated areas and of the population of the province and of its divisions for the years 1855-1869. It is made up from the Tables of Statistics of British Burma for the years 1854-65, and the Administration Reports of succeeding years.

Table of cultivation and Population for the years 1855 to 1869.

TABLE No. 1.

Years.	ARRACAN.				PEGU.				TENASSERIM.				BRITISH BURMA.				Probable immigration.
	Area of cultivation.	Ratio of cultivation to population.	Population.	Ratio of increase.	Area of cultivation.	Ratio of cultivation to population.	Population.	Ratio of increase.	Area of cultivation.	Ratio of cultivation to population.	Population.	Ratio of increase.	Area of cultivation.	Ratio of cultivation to population.	Population.	Ratio of increase.	
	Acres.				Acres.				Acres.				Acres.				
1855-56 ...	353,855	0·97	366,310	...	539,808	0·85	631,640	...	181,681	0·71	254,605	...	1,075,374	0·86	1,252,555	...	...
1856-57 ...	382,663	1·04	368,018	0·47	662,664	0·84	789,105	24·91	203,915	0·82	249,348	2·07	1,249,242	0·88	1,416,471	13·17	132,602
1857-58 ...	377,832	1·03	366,307	0·48	756,870	0·90	840,203	6·48	201,743	0·74	272,193	9·18	1,336,445	0·86	1,478,703	4·38	27,320
1858-59 ...	362,231	0·98	369,314	0·82	849,077	0·95	890,974	6·04	222,667	0·78	284,649	4·54	1,433,975	0·93	1,544,937	4·47	29,266
1859-60 ...	370,753	0·99	372,952	0·98	784,731	0·83	948,731	6·49	231,643	0·79	292,902	2·91	1,387,127	0·86	1,616,643	4·64	33,083
1860-61 ...	376,158	1·01	373,542	0·16	856,188	0·82	1,041,340	9·76	249,142	0·75	332,542	13·58	1,481,488	0·86	1,717,424	6·24	60,365
1861-62 ...	370,912	0·98	376,306	0·74	856,767	0·74	1,150,189	10·43	257,546	0·69	371,402	11·67	1,485,225	0·78	1,897,897	1·51	137,537
1862-63 ...	359,710	0·94	381,985	1·51	904,106	0·72	1,244,385	8·29	254,234	0·65	394,264	6·16	1,518,051	0·75	2,020,634	6·46	75,290
1863-64 ...	363,441	0·94	386,134	1·09	964,617	0·74	1,296,874	4·23	261,893	0·64	409,033	3·75	1,589,951	0·76	2,092,041	3·54	20,891
1864-65 ...	377,012	0·91	414,640	7·39	991,102	0·74	1,350,989	4·16	273,289	0·63	430,551	5·26	1,641,403	0·75	2,196,181	4·96	51,839
1865-66 ...	...	...	428,042	3·23	...	...	1,401,312	3·73	...	...	443,695	3·06	1,789.100	0·79	2,273,049	3·5	21,963
1866-67 ...	410,729	0·93	442,705	3·43	1,152,324	0·80	1,442,469	2·94	318,149	0·71	545,279	0·36	1,881,202	0·81	2,330,453	2·5	...
1867-68 ...	415,523	0·93	445,483	0·63	1,172,986	0·83	1,482,014	2·12	377,774	0·81	464,815	4·39	1,956,644	0·84	2,329,312	2·65	4,739
1868-69 ...	401,726	0·89	453,312	1·76	1,169,620	0·79	1,480,581	4·34	373,096	0·81	462,090	0·6	1,944,442	0·81	2,395,985	2·86	8,440

N. B.—In 1867-68 a population of 63,000 mouannti Kareens was left out of the Pegu Division Returns, and continues to be so.

29. *Immigration &c.*—The table is divided into four parts, one for each of the Divisions, and one for the whole Province. Each part shows the area of cultivation, the number of people, the ratio of ground cultivated to the number of people, and the ratio of increase during each year. To the part relating to the Province is given the approximate immigration during the year. There is reason to suppose that the increase of the population is 2·5 per cent in each year, exclusive of immigration. Deducting this amount from the actual increase, the result is the approximate immigration as shown. This rose during two years to over 130,000 persons, and in ten years amounted to yearly 600,000. The point most worthy of attention is, that during the last three years given, the immigration has almost ceased. This is confirmed for 1868-69 by the Administration Report * for that year where an excess of only 3,900 of immigration over emigration is shewn. The ratio of increase for Pegu during the ten years was remarkably large, and at first it seems to have taken so many from the other Divisions that the population decreased. Tenasserim regained its number and keeps much above the normal ratio during those years. Arracan, on the contrary, is below the ratio, until 1864 when it rose suddenly to 7·39 per cent. There must have been an emigration from Arracan into Pegu during those years. This is well known to have taken place. The last three years indicate considerable fluctuation in the three Divisions, although the ratio for the Province continues steady. There must have been a considerable return of emigrants to Arracan from 1864 to 1867.

30. *Reason of immigration—Good land been thrown open.*—What is the cause of the immigration into British Burma? And why has it ceased? What is the explanation of the fluctuation in the ratio of increase? Why, during the immense immigration into Pegu from 1855 to 1865, was there an emigration from Arracan? Why the return to Arracan during 1864 to 1867? And why the renewal of a high ratio in Pegu in 1868-69? One answer may be found for all these questions, and it will be hard to find another answer common to all. The people were seeking cultivable land. When Pegu was first occupied it had been nearly depopulated. Large tracts of good land were available for cultivation. This was thrown open on easy terms and crowds rushed in from Upper Burma, from Tenasserim, and from Arracan to occupy it. The new comers spread over every corner of the country seeking the kind they wanted—fertile lands, free from floods and inundation, little liable to drought, within easy distance from market, and only requiring the labor of individuals to clear, to plant, and to reap. Markets were simultaneously opened for the produce; rice has been the article most demanded, or most suitable to the land, and the power of the people to cultivate. This has occupied nine-tenths of the area cultivated; all other kinds of cultivation keeping a constant proportion to it. Arracan had been long under British Rule, the population and cultivation had increased; till most of the good land had been taken up. The area of cultivation remained stationary there during nine years of the exodus to Pegu. The new land in Tenasserim afforded the same attraction as that of Pegu. At last both Pegu and Tenasserim had little more land to offer on the same terms. Every spot had been searched out and occupied. The immigration from foreign territory ceased. The Arracanese returned to their own country in 1864, apparently in disgust; they found little relief there, and the exodus re-commenced in 1867. From Tenasserim there appears to have been a flow in 1866, a reflux in 1867, and another exodus, actually diminishing the population in 1868. In that year new land was thrown open by roads and by the embankments in Pegu, and the ratio of increase sprang up to 4·34 per cent.

31. *Paucity of cultivable land.*—The paucity of cultivable land has forced itself on the attention of the Settlement Officers.* It has been asked—"What is meant by uncultivable waste land?" A definition is given when it is stated that, except "rock and sand, most other des-

*See Report on Revenue Settlement Operations for the year 1867-68 Vol. I, page 29.

* Page 28, paragraph 49. "Probably the most remarkable figures given are those which show the emigration and the immigration, from which it will appear that although there were 64,827 immigrants, yet there were no less than 60,928 emigrants." It is said that this flow was principally from District to District.

criptions of land are culturable." The synonymous terms culturable, cultivable, and cultivateable, may have different meanings, and the above definition is true when it is meant that by the application of all the resources of art, most land can be made to yield some return. But when the words are used with reference to land cultivated by a people in a low state of civilization, the resources at their command, their education in the use of them, their practical habits of life, and their power of organising individuals into bodies with united efforts for common ends must be considered, and weighed against the difficulties to be overcome before the land can be made profitable. The Burmese are accustomed to live in the plain land, their methods of cultivation are rude, and their appliances imperfect, while the instances in which they have combined under the influence of the local officers, or of their own head men, for works of extended utility, as embankments, roads, or irrigation works, are sufficiently rare to show that not much reliance can be at present placed on this means of making land cultivable.

32. *Evidence of Settlement Officers.*—On examining closely the report of the Settlement Officers for 1867-68, it will be seen that, generally, some conditions require applying to the cultivable waste land to bring it into relation to the resources and wants of the people. In the Akyab District the land is in some measure classified; and out of 37 circles settled, 20 are described in such terms as (Vol. I p. 77) "having a considerable portion of waste land, but little or none available for cultivation." "The (p. 59) available waste land, is mostly high and unsuitable for cultivation." "There (p. 58) is plenty of waste land, but being high it is altogether unsuited for cultivation," and so on. Eleven have good waste land available, but in some circles the quantity was small, and would soon be taken up. Four have poor waste land available, and two are flooded so that they cannot be cultivated. In the Sandoway District (Vol. I p. 105) five circles are described and it is mentioned that all the good land near the river or market is occupied, and waste land is only to be got in remote and difficult parts of the country. The Ramree Settlement Officer, in speaking of his District, says (Vol. I p. 94) —"The great inducement to take leases, *viz.*, adjacent waste cultivable land is wanting to some extent." In the Amherst District, refering to paddy cultivation, out of 50 circles settled it is said of one—"The amount of waste land available without heavy expense for drainage or embankment, is very small," of another, of "4,833 acres only 838 are under cultivation. This is owing to a large amount of land being damaged by salt water, and damaged so badly as not to be reclaimable, except at a cost not likely to be incurred at present;" of another, "the waste land available for cultivation at a moderate cost of fair drainage may be estimated at 5,000 acres," and so on for 27 circles.* Six circles have no waste land at all. Of four, the waste land is not described. Only eight are said to have good waste land available. The remainder have the waste land so poor, or so far from market, that little spread of cultivation is anticipated. In Myanoung District several of the circles are mentioned as liable to inundation with no room for extension of crops. Most of those behind the embankment have abundant waste land, as well as two or three others. Of the majority, nothing is said about the waste land. The Toungoo District had sixteen circles settled. Of these two had little or no waste cultivable land, seven could only have cultivation extended by irrigation on embankment works, one is not described, and the remaining six have good cultivable land available, but amongst them roads and irrigation works are much required. In the Prome District Report the lands are not classified, but out of 96 circles settled, there is shown a decrease of cultivation in 58, mostly owing to poverty of the soil, inundation or want of irrigation, slight increases in only 19, the rest remaining unaltered. In the other

Settlement Report for 1867-68 V. 1.

Vol. III, p. 115, paragraph 306.

Vol. III p. 81 paragraph 164.

* See also p. 123 paragraph 2, "This was the constant argument of the villagers. The great benefit offered us in the settlement rule is the free extension of our cultivation for five years, but where are we to extend it, unless you keep water out for us?" Mr. Tracy puts down about 5,000 acres as cultivable out of 13,000. But I doubt if there are 5,000 acres of vacant Kweng land that could be taken up with any certainty of profit for paddy cultivation, two or three days heavy rains would swamp the whole beyond remedy.

Districts the waste land available is either not generally mentioned, or the description is in such unprecise terms as not to be available for comparison.

These statements are made by the persons most competent to give correct information, who visited the localities referred to, had most of the cultivators before them, and were prosecuting enquiries directly bearing on the matter. Nearly one-half the cultivated land in the Province was visited, and, as it may be assumed that not much land exists available for present cultivation without some settlers near it, the characteristics of the circles settled fairly represent the condition of the whole Province. It is almost certain that as the new settlers were free to select, they have chosen in each circle the best ground, and, even when waste cultivable land remains, it must have disadvantages compared with that already cultivated. There is abundance of valuable land in the Province which requires some condition applying—irrigation, embankments, or roads—before it can really be made serviceable, but without which it is useless.

33. *Other resources examined.*—It may be asked—are the people not by better appliances improving the ground now cultivated? Is there no probability that, if land is not to be obtained by other means, they may themselves undertake the works required? Or cannot they turn to other and more remunerative occupations, and thus improve the commerce of the country? The Settlement Reports state that a wide-spread and general deterioration of the land through over-cultivation of one grain has taken place. Rates of land tax have been lowered in various localities on this account. In some places garden-cultivation is extending and improving, but this bears a small proportion to the wants of the people. The rude implements and methods of cultivation in use for centuries are still unchanged, and no sign has yet appeared of improvement. Possibly alterations may take place in this, but there is now nothing in progress to compensate the limitation of the land, or its tendency to deteriorate.

34. *Cultivators cannot be expected to reclaim land on large scale.*—In some places cultivators have combined under competent leadership to effect works of improvement in their neighbourhood. When the motive is sufficiently powerful, when the parties who have the means and the opportunity are certain to reap the reward, it is probable that small works may be executed by the cultivators. But it is not so much for the sake of the persons at present in possession of surplus means and cultivation enough for their wants that new land is needed. It is for the surplus population of the poorer districts, generally needy, seldom acting in combination, and possessing little influence over others, that a possible extension of cultivation is required. It is for the 2½ per cent of new population added every year within the Province, amounting to over 60,000 persons last year, and increasing in numbers every year, that provision for expansion requires to be made, as well as for immigrants. It can hardly be expected that well-to-do cultivators will reclaim fresh land for others to reap the benefit. And were it likely, as the consequences of failure are so disastrous, it will not be desirable that they should undertake them on a large scale till they have had practice or good examples placed before them.

35. *Agriculture the great employment of the people.*—So far from there being any new employment opened to those who may wish to give up agriculture, it is probable that some of those now otherwise employed will be forced back on the land for their livelihood. The principal occupations hitherto open have been in the forests, in fisheries, in weaving, in cleaning paddy, and in making salt. It is well known that owing to the diminution of the timber trees, and the systematic manner in which the forests are worked, comparatively few people are employed on them, and there is no probability of a large increase. It is not so generally known that the number of persons engaged in the fisheries tends to decrease, rather than enlarge. Of deep-sea fishing there is little or none. The inland fisheries are limited in extent, and have long been worked as far as possible. The work is getting better organized and now speculators work on commercial principles with the fewest possible men, where village communities used formerly to share the profits. In making clothing for

the people, the weavers have to sustain a fierce competition in every bazaar against English goods manufactured by machinery. From the history of contests of the kind, the result of this may be foretold. The importation of these articles continues rapidly to increase. The value of piece goods, cotton twist, and yarn, imported in the year 1867-68, was £1,450,917, the average of the five years it ended being £1,139,972. A portion of this passed through to Upper Burma, but the total shows the little likelihood there is of a spread of industry in the direction. Amongst the first objects visible on approaching the sea-ports of Burma, are the large mills where paddy is transformed into rice by machinery, worked by English coal, carried out at nominal rates as ballast in the rice ships. Year by year the trade extends, and is passing out of reach of the laborers, who grind in rude mills by hand. It is stated* that Europe salt is occupying the market in Burma, and the local production will probably be extinguished. In every existing employment there is thus a prospect of diminished room for labor; no new branch of industry has been opened and no new article of produce appears in the list of exports. There is, then, an additional necessity for land to meet the new requirements.

Administration Report 1867-68.

Though the evidence now indicated may not be sufficient to prove any immediate pressing want of cultivable land, it will probably be allowed that the subject must soon be of great practical importance, and every means proposed of opening out new tracts for cultivation will merit attention, in order to secure in time the adoption of that which will best effect the object.

36. *The best land is in the Irrawaddy Delta.*—The embanking of the land of the Irrawaddy Delta offers the greatest returns for money and labor expended for that purpose. The fertility and situation are such as to give the greatest economic rent of any lands yet uncultivated in the Province. This has been defined by Professor Cairnes as "that portion of the value of the returns from land which remains after the outlay of production has been re-placed with customary profit." To illustrate the meaning and importance of this in its present connection, the following Table No. II has been drawn up, showing the number of cultivators and area cultivated in each District in the years 1867-68 and 1868-69.

* Administration Report for 1868-69 page 113—"A very heavy importation of salt from England and the Continent of Europe was made into Pegu during the year, which found a pretty ready market at prices which have no doubt paid the importers, but which are very much below those hitherto realized for the salt manufactured in this Province. It yet remains to be seen whether the population generally will become consumers of foreign salt, but should they do so and the difference in price in favor of the imported article will certainly be a great inducement to them, the local manufacture will be greatly reduced, and probably, in course of time, be almost extinguished as it has been a long the sea-board of Bengal, but this will not be a matter for regret, for, although the salt manufacturers may for a time be distressed, they will soon find means of utilizing their labour in this sparsely-populated country, and in the end, perhaps, find the land a more profitable investment for their toil than the sea."

Table No II.

Table of Population and Agriculture for the years 1867-68, 1868-69.

Districts.		Population.				Ratio of increase or decrease.	Agriculturalists.		Area of assessed and cultivated ground.				Ratio of cultivated ground to agriculturalists.	
		Total 1867-68.	Total 1868-69.	Increase.	Decrease.		1867-68.	1868-69.	Total 1867-68.	Total 1868-69.	Increase.	Decrease.	1867-68.	1868-69.
Arrakan ...	Akyab	266,853	271,953	5,100	...	1·88	36,391	30,879	294,097	280,400	...	13,697	8·08	9·08
	Ramree	125,519	127,239	1,720	...	1·35	18,687	24,596	85,089	85,326	237	...	4·55	3·47
	Sandoway	45,176 7,935	46,185 7,935	1,009	...	1·87	9,190	9,442	36,337	36,000	...	337	3·95	3·81
Pegu ...	Rangoon	351,417	358,075	6,658	....	1·86	41,618	41,621	404,956	408,334	3,378	...	9·73	9·81
	Bassein...	274,540	291,217	16,677	...	5·73	35,693	32,768	228,632	222,457	...	6,175	6·40	6·79
	Myanoung	380,505	393,627	13,122	...	3·33	58,470	58,924	239,698	236,906	...	2,792	4·10	4·02
	Prome	332,493	360,712	28,219	...	7·82	55,598	56,297	264,861	265,379	518	...	4·76	4·55
	Toungoo	80,059	76,950	...	3,109	4·04	11,383	...	34,839	36,544	1,705	...	3·06	...
Tenasserim ...	Amherst	219,538	222,358	2,820	...	1·27	29,777	29,852	200,944	200,991	47	...	7·03	6·73
	Tavoy	66,974	68,749	1,775	...	2·57	...	20,233	62,525	60,924	...	1,601	...	3·01
	Mergui...	41,688	42,550	862	...	2·00	7,263	7,263	37,805	37,686	...	119	5·19	5·19
	Shwe-gyeen	126,017 10,598	128,433	...	8,182	6·40	19,359	20,567	76,500	73,495	...	3,005	3·95	3·58

N. B.—The quantity of ground assessed sometimes differs from that cultivated. Where this is the case the largest has been chosen.

37. *Law of cultivated area.*—In the last column are given for each District the average amounts of the cultivated land in acres to each cultivator. This, when studied, reveals a remarkable law. It is that the area cultivated by each person bears a direct proportion to the nearness to markets and to the fertility of the soil. Thus the Districts with the principal sea-ports of Rangoon and Akyab have about ten and nine acres, respectively, for each cultivator. The other sea-port Districts of Bassein and Amherst come next, each with nearly seven acres. The sea-coast Districts, far removed from the ports, and entailing a long sea journey for the produce, fall very low. Ramree, Sandoway, and Tavoy are between three and four acres. Mergui has over five acres, and the inland Districts range from 3 to 4·5, the highest being Prome, with a good market in Upper Burma, and the smallest Toungoo, with a long and difficult river communication to Rangoon &c. In examining the Districts themselves the same law holds good. The Settlement Reports for 1867-68 show that in the more favoured portions of Rangoon District, the proportion is often 20 acres and sometimes 30 per individual; in the remoter parts it falls to five and four acres per man. In the three-acre District of Toungoo, the circle close to the town has 610 lessees of 4,339 acres or 7·0 acres per man. In a remoter circle 179 acres were leased to 81 men, or a little over two acres each. Again, in Ramrée 1,695 acres were leased to 1,142 owners, or less than 1½ acre each, though sometimes it appears more than one lease was given to the same owner. The information as to proportional area is not always given, but sufficient is stated to show the universality of the law, that as the distance or the fertility are unfavorable, there is a smaller area cultivated.

38. *Law of fertility.*—It is remarkable also that the fertility often diminishes as the distance increases. There is not much evidence bearing on this point in the Settlement Reports. In the remote District of Ramree, it is said (Vol. I, page 96) that in one part the average produce per acre was 12½ baskets, in the Myanoung District poor land gives 20 to 30 baskets (Vol. 2 page 83.) The average is 40 to 50 baskets, though near Henzada the yield sometimes rises to 80 or 90 baskets on good land. The size of the basket is not always the same. At Henzada, a basket of paddy ranges in weight from 50 to 56 lbs. It may be assumed, for comparison, to be much the same as this in other parts. Rangoon and Bassein Districts have generally the same kind of land as Myanoung, Prome District is poorer, the best land giving 40 to 50 baskets. Of Amherst it is said (Vol. III, page 59) the land "in a good year might produce from 60 to 70 per acre;" but in a bad season "only 40 baskets." In the Reports for this District expressions are found as (Vol. III, page 70)—"The Kwengs just below the high land are very poor, some will not yield more than 15 or 20 baskets per acre." "The paddy lands nearer the river are good" (page 126), "the best land lies in a small circle near the coast." In the remote Tavoy District a very large proportion of the land is shown as yielding less than 15 baskets per acre, and hardly any above 50. This rule as to decrease of yield may not always be true, but it is sufficiently prominent to enhance the importance of the diminished quantity of land actually cultivated by each person in the remote Districts. The smallness of area is easily explained. Thus in one case it is recorded (Bassein Report, Vol. II, page 57) that the rates have been reduced "in consequence of the cultivation being at the bottom of the hills, and at a distance of about 40 miles from the banks of the river; the result is the paddy has to be conveyed to the river side on carts, which is an extra expense of about 10 Rupees per 100 baskets. This was one reason, and the other that the soil is not so productive." The 10 Rupees hardly represents the full disadvantage. The journey would be altogether 80 miles, and generally through forest. A cart drawn by two bullocks carries only 25 baskets; it travels from 15 to 20 miles per 24 hours. It cannot go in the heat of the sun, lest the beasts should be injured, nor on dark nights, on account of tigers; a company must go together for fear of dacoits, and they must hasten back lest their village be attacked; so that the grain must be hurriedly sold and the purchase of goods made, with a hurried return back. It is found that very little produce can thus

be disposed of in one season. In other parts (Vol. I, page 105) "the inland Kwengs are remotely situated, with hills intervening between them and the villages, so that the produce has to be carried to the villages on men's shoulders before it can obtain any value." The sea-coast Districts have the same causes at work, in the long boat journeys by sea. A glance at the topographical map of Burma shows how largely these causes operate.

39. *Results of the cultivation of good and of bad land compared.*—It thus follows that while in the best Districts the labor for a cultivator and his family on the plot of 15 or 20 acres may yield 1,000 baskets, whose price on the spot is 750 Rupees, in the less favored parts a family may be altogether occupied on their plot of 1½ acres in producing what will be worth only 10 Rupees (see Vol. I, page 96) a little more than pays their taxes. The money figures do not give the full importance of the difference. The articles purchased with the same money in the remote bazaars must be of smaller value than in those near the town or principal communications, so that the actual return to the cultivator for his labor in the shape of comforts or luxuries is still more disproportionate. And the same difference obtains in the higher enjoyments of life. It can be shown that while in some parts the people by all their endeavours can procure but a bare subsistence, in the richer Districts, pagodas and rest-houses for travellers are built, religious offerings are frequent, monasteries and schools abound, and education is liberally and generally offered, free of cost, to all who choose; theatricals flourish; exciseable articles are largely consumed; better houses, better wearing apparel, and better food are in use, and English goods are much in request; while from the distributive character of the civilization, and the practical benevolence of the people and their religion, the standard of living of those who are better off represents, in a great degree, that of the community around them. The direct and indirect contributions to Government are in much greater ratio. Thus in one circle close to Rangoon (West Maline) 12,852 acres are leased to 866 owners, giving holdings averaging 15 acres each. The rates on this land are mostly Rupees 2 to Rupees 2-4 per acre, making each man's contribution in land tax above 30 Rupees yearly. In Ramree, 1,659 acres leased to 1,142 owners, gives a revenue of only Rupees 2,146 or Rupees 1-14 of land tax for each person. The other direct contributions can be calculated, and the indirect ones conjectured. And as the imported goods are mostly used in these wealthier Districts, the results of the contrast can be made to stand out in a startling form, and to show how little beyond mere existence remains for the dwellers in the poorer Districts, and how little their labor contributes to benefit themselves, the Government or the world at large.

40. *If new land is opened out it will speedily be occupied.*—It is not the fault of the people that the net result of their labors is so small. The same persons in different parts of the Province produce very different results. The generality of the law of the increase of actual labor in proportion to its effectiveness has been indicated. It proves that when good and well situated land is offered it will be worked to the full powers of the cultivator, whose energy will be stimulated by the hope of enjoying real returns for his efforts. The eagerness with which the land opened out in Pegu has been availed of, the earnest striving to better their condition which the rapid spread of cultivation in the good land proves, and the immense flow of population from the poorer to the better grounds of Burma, show how they have improved every opportunity as yet offered to them. The same motives are still at work. Upper Burma is as ready as before to throw off 600,000 emigrants in ten years. It is sometimes stated that the population of that territory has been diminished by the former efflux; but the well established law that in the absence of preventive checks or extraordinary occurrences, a people doubles its numbers in from 20 to 30 years has been lost sight of. There are probably three million persons in Upper Burma, and, if it is assumed that the increase is 2·5 per cent each year, 75,000 persons could be yearly parted with, and the population continue constant. In

Lower Burma from sixty to seventy thousand persons pass from District to District, not as mere visitors, but as settlers wanting to work for a living. And here the natural increase must be over 60,000 yearly, who must be provided for. In Pegu there has been in the last year or two new tracts opened out. Last year the increase of population in the Myanoung District was 7·75 per cent. This sudden rise took place immediately on the new roads being opened in Tharrawaddy, and the completion of the Myanoung embankment. Were the remaining 10,000 miles of the Delta to be suddenly thrown open, it is almost certain that the movement of 1854-63 would be repeated on a greater scale,—the poorer Districts would be depopulated, Upper Burma would not only lose its increase but probably a great portion of the resident population; and since, as Table I shows, the number of the population appears to maintain much the same ratio to the area cultivated in the rich land of the Delta, amounting to over one person per acre, the accession of population in this part alone would be over six millions, implying an increase of wealth and property to each person far in advance of the standard of the Province at present, and an immense total increase. If the opening or rendering cultivable of new land does not keep pace with the population, one of two things will take place, either the remote and inferior lands must be fallen back upon, when the new holdings will approximate in size to those in Ramree, and be as little profitable, or the present cultivated area will be sub-divided, and the holdings diminished in size. In the case of immigrants or changes from one District to another, the former result is likely; but the families of present cultivators will probably continue to increase on their own lands and sub-divide them. There is reason to believe that this latter result is already taking place. On turning to Table No. II, it will be seen that the number of cultivators increased during the year 1868-69 from 321,037 to 332,442, while there was an actual decrease on the assessed or cultivated ground of no less than 21,841 acres, showing that some of the fallow and poorer land had been given up. There was a diminution in the average size of the holdings for the Province from 6·13 to 5·85 acres This must mean a smaller gross produce, and a still smaller net produce; and, when coupled with the fact that no new employments are opened out, a general diminution of the means of enjoyment for the whole of the people. It must also signify a diminished power of exporting; and, therefore, of importing; and a smaller ability to pay the direct and indirect taxes of Government. When to this it is added that no tendency is apparent of things to mend of themselves; that, as the means of enjoyment diminish and a lower standard of living becomes general, there is reason to apprehend, from an extensive series of observations, that the ratio of increase of the population will rise and make the evil worse, it will, I think, be admitted, that the appearance of paradox is removed from the statement that British Burma is now more in want of good land than of population and that the means of increasing the former is more worthy of attention than the latter.

See Administration Report, 1868-69, page 28.

41. *Value of the Myanoung Embankment land.*—The land to be protected by the embankment is intersected by navigable streams, and within easy reach of the two sea-ports of Rangoon and Bassein. It is for situation the best land in the respective Districts, and the price of the produce of the parts now cultivated averages little less than the prices at the ports. Near the town of Myanoung the average produce is 40 to 50 baskets per acre and the price ranges from 55 rupees to 80 rupees per 100 baskets. At Okpho the produce runs from 30 to 50 baskets per acre, and the price 35 to 65 rupees. Thus the produce price per acre at Myanoung is from 22 rupees to 40 rupees, and at Okpho 10½ rupees to 32½ rupees. The price varies all along the river bank from 55 rupees per 100 in the harvest time to 80 rupees in the rains; and as the land now protected is nowhere more than 10 miles from the bank, the value of the produce will average only 5 rupees less than this; while that of the land already taken up near the river bank will fully equal it. The ground behind the Myanoung embankment is said to be not so rich as that nearer

Henzada. It is, however, better than that already cultivated, lying lower, and thus continuing more damp, which is the great requirement for rice. It is almost all good land, and the yield will average 50 baskets per acre, the produce price per acre thus ranging from 25 rupees to 35½ rupees. Judging from analogy of advantages, it will probably become 8 acre or 10 acre holdings. Up to the end of 1868, the land thrown open was comparatively little, and there has been barely time yet for the full advantage of the ground to be widely known. As it is, there is a line of cultivation spreading along the side of the embankment; but as the holdings do not attain their full size for a few years, owing to the difficulty of clearing, and as the revenue is not collected till from one to five years after the clearing, the statements cannot give precise information about the progress made.

42. *The Embankment Maps do not show the reclaimed cultivation.*—In the Chief Engineer's direction for colouring the maps, it was ordered that the land altogether reclaimed from floods should be shown coloured sienna, while that formerly cultivated, but liable to be injured by very high floods, should be shown yellow. There are no maps existing which permit this distinction to be made. The revenue maps have not been brought up year by year. The latest map is that of the Topographical Survey executed in the years 1863 to 1865. The revenue maps I obtained from the Deputy Commissioner are of earlier years, not dated. The map of the embanked lands is made up from the topographical map; and though the area cultivated since the embankments were made could be sketched in roughly, the result would be untrustworthy. A regular survey would have been expensive and was not permitted. The land reclaimed and cultivated is, therefore, not shown. If the head men of circles who are generally competent to measure land and plot roughly were to show on their maps of circles the land cultivated every half year, it would be sufficiently accurate to transfer to the large map and show approximately the progress made. The small maps of circles, now published by the Topographical Survey, will enable this to be done easily and correctly, as most of the creeks and land marks are shown.

43. *Economic rent of land.*—The outlay on the cultivation is the labor of the cultivators with their families, and occasionally hired labor, with the cost of a pair of bullocks. The cultivator is generally the owner. The value of this labor differs according to the District it is in. If it could be arrived at, it is obvious that the difference between this and the value of the gross produce would be the economic rent of the land. This may be learned in another way. The selling price of land near Okpho varies from 10 to 50 rupees per acre. Near Myanoung and Henzada it is rarely lower than 30 rupees, and sometimes it is 60 to 80 rupees. Assuming that the exemption from land tax is an equivalent for the cost of clearing, the annual value of the above prices will be the cultivators estimate of his share of the economic rent. The rate of interest all over the province is 4 per cent per month, with gold and jewels deposited, and 5 per cent for the best personal security. It is clear the price cannot be more than two or three year's purchase, which gives the cultivator's share in the above-mentioned lands as ranging from 5 to 30 or 40 rupees.

44. *Land tax assessment.*—The remainder is the Government share or land tax, which is generally proportioned to the rent. The mode of assessment is described in the Hand Book for British Burma (.p p. 238—248). The assessor is to learn.

1st.—The present rate of tax per acre.

2nd.—The average yield of paddy per acre.

3rd.—The average price of paddy on the spot and

4th—The distance from and means of facility of transport to the nearest great and constant market.

"It is to be assumed that the ordinary amount of the Government share of the paddy crop is one-fifth or twenty per cent of the gross produce." This rule was carried out in Ramree where the Settlement Officer says he found some lands rated at 34, 35, and 36 per cent; which he reduced to about or below 20 per cent of the gross produce value. As the price of produce near Myanoung and Henzada amounts to from 20 to 30 rupees per acre, the tax at the rate would be 4 to 6 rupees. But the Hand Book says—"It will frequently be found impossible to reconcile results obtained by mere measurement and calculation with what is assumed to be a fair remuneration to the cultivator, and with the rate already paid to Government;" so "a sound discretion" must be exercised in fixing the rate upon general considerations, such as the amount heretofore paid by the people, their own statements of their profits, and what they are willing to pay; and likewise to have regard to the general evidence of property or the reverse apparent in their dwellings and appearance." An examination of the rates show that they tend to a proportion to the economic rent approximating from five to ten per cent, though sometimes more. The land tax on the ground in the Myanoung embankment was formerly generally Rs. 1-8 per acre, but in 1867-68 the Settlement Officer altered the rates to Rs. 1-12 near the river, and Rs. 1-4 in the remote parts, leaving the middle portion unchanged; and the whole will still probably average Rs. 1-8 per acre.

45. *Land tax settlement.*—The settlement is optional on the part of the cultivator for terms of 3, 5 or 10 years, during which time he may take in as much fresh land as he can work without paying increased tax. He is permitted to keep one acre in every ten fallow, on 2 annas per acre. Remission of tax will be made for unavoidable loss, as heretofore.

46. *Land tax on reclaimed land entirely due to embankment.*—Only 12,000 acres of the 180,000 behind the Myanoung embankment were cultivated previous to its construction, and only 32 and 14 acres were taken up in the years 1862-63 and 1863-64. This was during the time when the immigration into Pegu in search of good land was at its height, and it is reasonable to suppose that there must have been some great preventive to cause this fertile and well situated land to be passed by. It is known that the greater part of it was yearly submerged, and, as simultaneously with the completion of portion of the work in 1865 large tracts were brought under cultivation, it seems certain that the spread of cultivation is entirely due to the effect of the embankment. The whole of the land tax in the portion cultivated since the work commenced is therefore an immediate return for expense of construction. Of the other returns in the shape of direct and indirect taxation on the cultivators, as well as on the traders and others in the neighbouring towns and villages, who are supported from the produce, and who, but for this land being thrown open, might be leading an unprofitable existence in some out-of-the-way one-acre District, nothing will be said. The land tax alone on the 168,000 acres available for cultivation will yield, when the whole is cultivated, an annual return of at least Rs. 252,000. It has been thought unnecessary to carry the whole of this amount to the credit of the work. One-fourth part of the sum received, or six annas per acre is set aside as an embankment cess, together with a charge of four annas per acre on the land previously cultivated. The two sums will amount to Rs. 67,500. The cess will not be a charge additional to the land tax, but is an arbitrary portion of it, as, since the land tax is fixed on the same principles here as in other parts, a further charge would place the land at a disadvantage compared with all other lands. It is expected that this cess will be sufficient to pay the whole of the interest off, with the annual charges; and, eventually, form a sinking fund to pay off the original cost. It is declared capable of modification, and can be altered to any amount within the limits of the land tax. The charge of four annas per acre is on account of the protection afforded to the land formerly cultivated, which was liable to destructive floods, but is now free from them.

(Signed) ROBERT GORDON,
Executive Engineer.

(b) From the Secretary to the Government of India, Financial Department, No. 394, dated Fort William, the 16th January 1872.

Read again Financial Resolution No. 607 dated the 30th May 1870, ruling that the embankment cess levied in British Burma shall be collected by the Local Officers of Revenue and the collections treated as canal revenue and credited to the Public Works Department.

Read an endorsement from the Department of Agriculture, Revenue and Commerce No. 401 dated the 7th October 1871, forwarding with papers a communication from the Public Works Department, sanctioning the recommencement of embankment operations in British Burma and referring for decision the question as to the system of Finance which should be adopted for the prosecution of all future embankment operations in those Provinces.

The Governor General in Council observes that other modes of showing the profit from Irrigation works in British Burma which were formerly discussed, having been laid aside, it is now desired that an account should be established in which the expenditure for constructing embankments shall be set against the land revenue derived from lands protected by the embankments.

2. The account of the returns from the outlay on embankments in British Burma should be outside the Revenue and Finance accounts.

3. The whole of the revenue from lands protected by embankments, cannot be credited to the works and even in the Administrative accounts outside the finance accounts, for abatements have to be made in the first place for the Thoogyees commission for measuring the land and collecting the revenue, and for the five per cent cesses for Roads, Police and Education.

Again it cannot be assumed that all increase of cultivation behind an embankment is so much gain to revenue. There will no doubt, as stated by Mr. Gordon, be immigration from other parts of a district or from other districts to the land protected by embankments. But the local increase of revenue from the immigration would represent a mere transfer of land revenue to the embanked portions of a district from other parts of the country and all such nominal increases should be carefully ascertained and excluded from the account.

4. The Governor General in Council accordingly considers that the annual accounts should be accompanied by a statement showing for three years the cultivated area, population, and land revenue of

1. The land assumed to be brought into cultivation by the embankment.
2. The remaining land in the district.
3. Total for the district.
4. Similar figures for other districts, not excepting those in which there are no embankments.

Any decrease in No. 2 and 4 unless otherwise explained, would probably fall to be deducted from No. 1.

5. The receipts from capitation tax, Stamps,or any sources other than the land tax in the tracts protected by the embankments will not be credited to the works, they being set off against the charges of Civil Administration.

6. Simple interest on the capital outlay should be charged to the works in accordance to the general rule on this head.

7. There remains to consider a starting point for reckoning the past increases of cultivation, of which the land revenue is to be credited to existing embankments.

8. For the Henzada embankment there was a charge of Rs. 3,861 for construction in 1863-64 and none for 1864-65 and 1865-66. The real expenditure began with half a lakh in 1866-67, and went on increasing to a total cost of Rs. 341,442 at the end of 1869-70, yet the increase of land revenue as due to the embankment is computed over the amount of land revenue in 1861-62 *viz.*, Rs. 22953. Whereas it ought to be reckoned apparently over the land revenue of the much later year when the first considerable outlay in 1867-68 became productive. The extra credit of at least Rs. 30,000 taken by Mr. Gordon would turn the surplus shown by him for the Henzada embankment into a serious annual deficit. In paras 16 and 46 of his report Mr. Gordon has given reasons (not quite conclusive) for reckoning the increase of cultivation behind the Kyangheen and Myanoung embankments from the years 1866-67 and 1863-64 respectively; but he has not explained his reasons for reckoning the increase for the Henzada embankment for 1862-63 that is over the land revenue 1861-62, which preceded by two years the first small outlay of Rs. 3,861 and by six years the first considerable outlay in 1867-68 which could not have become productive till 1870-71.

9. Referring to para 46 of Mr. Gordon's report wherein he ascribes a large increase of cultivation in the Myanoung District in 1865-66 to the construction of an embankment because there is no other adequate explanation of the circumstance, His Excellency in Council would suggest an enquiry whether some of the increase in this and other districts, is not attributable to the assessing of lands which before the enquiries of the Settlement Department may have been concealed from the Revenue Officers and so have escaped taxation. The Chief Commissioner should also reconsider in the revenue branch of his Secretariat from what year the increase of cultivation behind the Henzada embankments may be reckoned as fairly attributable to the expenditure in constructing that embankment.

(c) No. 669 I.

GOVERNMENT OF INDIA,

PUBLIC WORKS DEPARTMENT.

IRRIGATION.

Simla, 2nd November 1871.

Embankments in British Burma.

Read the following Despatch.

INDIA OFFICE,

London, 28th September 1871.

Public Works No. 65.

To

HIS EXCELLENCY THE RIGHT HON'BLE THE GOVERNOR GENERAL OF INDIA IN COUNCIL.

MY LORD,

I have received your Excellency's despatch July 14th (No. 80) 1871, on the subject of the embankment operations in British Burma, together with the excellent report by Mr. Gordon, which accompanies it.

2. The remunerative character of these important works appears now to be fully established and I shall watch their progress with much interest.

3. The system of finance, under which the embankment works in British Burma are in future to be conducted, has I perceive, been referred to the Agriculture and Finance Departments of your Government. I await the result of this reference.

I have &c. &c.

(Sd.) ARGYLL.

Ordered that the foregoing be forwarded to the Chief Commissioner of British Burma for information.

(Sd.) C. H. DICKENS, Col., R. A.,

Secretary to the Government of India.

(d) Extract from a Minute by the Hon'ble Ashley Eden, C. S. I., *Chief Commissioner of British Burma, on the Chief Engineer's Revenue Report on Irrawaddy Embankments from 1862-63 to 1873-74,— (Dated Rangoon, 15th October 1874.)*

The Henzada section is certainly very encouraging. The work for reasons explained in paragraph 28 of Colonel Oliphant's note, was delayed by discussions, while interest charges were accruing on incomplete and therefore unremunerative works. These works were re-commenced in earnest only in December 1871, and 80 miles have been completed. Of the vast area of land thus protected, comparatively little has yet been taken up; there has not been time for this, but the Deputy Commissioner tells me, that during the current year, there is a most remarkable rush for land in the protected tracts; large villages and even towns are springing up and the whole aspect of the country is changed. In the presence of such results, Government can afford to face some little disappointment in the two upper schemes. The extent of country entirely protected and reclaimed by that portion of the Henzada section is over 800 square miles in extent, and it is estimated that it contains 400,000 acres of arable land which have by these works been rendered capable of cultivation. The whole of this land will be gradually taken up in a few years. Up to the close of 1873-74 there had already been an increase of acreage as the result of the works, of 51,185 acres, and of Rs. 83,254 of land revenue, the total outlay of capital on the entire section was Rs. 10,50,000, but of this Rs. 5,00,000 were expended in portions which had not begun to be productive, and therefore, as shown by Colonel Oliphant, the receipts for direct increase of land revenue alone, in that year, amounted to a return of more than 15 per cent on the productive capital. But if the further indirect benefits and increase of revenue, claimed as a result of the undertaking by Colonel Oliphant, be taken into account the Henzada section of the embankment has, in twelve years, after paying all expenses of interest and management, returned to the state more than 50 per cent of the Capital hitherto expended on it, and this too under the most unfavourable circumstances.

The position of the Government in Burma is that of a landlord with an improvable estate; whatever is done in the way of reclamation is both directly and indirectly an increase to its rent rolls; it is not improving the estates of zemindars and other landholders with fixed revenue payments, it is really improving its own fields and bringing peasantry to cultivate what has hitherto been an almost impenetrable waste. The general report of the administration, and especially the trade returns, will best show the enormously increased productive power of the Pegu division. Every year will show, it is to be hoped, similar progress, and it is not only in the way of direct revenue that these embankments are a benefit to the administration; they facilitate the working of every department; no roads could be made till the water was kept out of these tracts, the Police and Revenue Officers could only with difficulty penetrate to interior villages, and thus while intercourse between the people and the District Officers was most difficult, the interchange of produce was only possible during the rainy season, indeed, it would be difficult to describe in detail the whole of the benefit which these great schemes of reclamation have already conferred and will still further confer on the population.

(e.) *Extract from a Minute by* A. RIVERS THOMPSON, ESQ., *Officiating Chief Commissioner British Burma, on the Chief Engineer's Revenue Report on Irrawaddy Embankments for 1874-75.—(Dated Rangoon, 5th November 1875.*

The figures in Colonel Oliphant's note, which are based on detailed returns from the districts affected by the embankments, and after personal communication with the Deputy Commissioners, speak for themselves. The financial results of another year's experience, exhibiting a continued increase of revenue from more extended cultivation, the direct consequence of these works, and a material reduction in the charges of maintenance, are quite satisfactory. These results are more established in the completed portion of the works, *viz.*, in the Kyangheen and Myanong sections, which though comparatively speaking of limited area and promising no very wide prospects of future reclamation, indicate clearly enough the immediate advantages which will be secured on the completion of the more extensive and important works now in progress on the Henzada section.

The capital account of this section is still an open one, and from the work that remains to be done, it is estimated that two more years must pass before the contemplated series of embankments are finished on the main river, and on the Nga-woon branch, which passes through the Bassein District. As far as the work has gone, the results financially are favorable, shewing a net profit on the working of this section for the year of Rs. 57,682, even making allowance for increased charges of maintenance and interest on capital.

With the completion of these sections to Donabyo and the Taboo choung, it is represented that about 900 square miles, will be brought under protection, and that at least 400,000 acres comprise good arable land capable of cultivation and assessment. I understand that a more favorable estimate than this is taken by Mr. Gordon, the able officer in direct charge of the works, as regards the culturable area which the embankments will eventually secure, but in the absence of more detailed local information as to the capabilities of this wide tract of country, it is impossible to state with any accuracy the ultimate extension of the cultivation in these two districts, and for our present purpose, the more cautions limit is prudently admitted.

The question of the indirect effects which the embankments exercise on the population of the country, and the incidental advantages arising from their settlement in it, were fully discussed in the review of the operations of 1873-74, in last year's report. If I allude to the subject again, it is only from the wish to confirm what has been stated and is now admitted by the Government of India, as to the justice of the claim asserted, that in considering the financial results of this work, credit can be taken for a portion of the very large remunerative returns which the country derives therefrom.

(f.) *Extract from Minute by* C. U. AITCHISON, ESQ., C. S. I., *Chief Commissioner, British Burma, on the Chief Engineer's Revenue Report on the Irrawaddy Embankments for 1876-77,—(Dated Rangoon, 10th April 1878.)*

It is unnecessary that I should repeat the figures set forth in these tables and reviewed clearly and concisely in Colonel Trevor's report. The net outcome appears to be that the Kyangheen section will never be a paying concern but will probably show an annually recurring deficit of about 4 per cent; that in all probability the Myanoung section will never do more than pay the interest on the capital outlay and will not even do that unless the land which it protects be much more largely taken up; and that it is to the Henzada section we must chiefly look to make the embankment scheme remunerative as a whole.

And here I must say that in my judgment it would be much better to leave out of the review all consideration of what are called indirect returns for which claim is made to the extent apparently of Rs. 662,262. The connection between these embankments and the increase of population or of rice export and the like seems to be much too remote to justify us in crediting the scheme with any of the capitation tax or the customs dues &c. It is by no means clear that the population settling in these lands does not to some extent migrate from other parts of the country; it is much more probable that the rapid growth of the population in the province is due to general causes. The embankments might with equal justice claim a share of the excise revenue or of stamps, as of customs dues. The railway for example does not get credit for savings effected in the movements of troops. If we went generally on the system of claiming indirect returns in the different departments of the Administration, the result would be that we should calculate our revenues five or six times over and produce utterly fallacious accounts. The proper way in my opinion is to credit the embankment scheme only with revenue which can be directly traced to it, *viz.*, the revenue from the fresh area actually brought under the plough, and the revenue (necessarily somewhat arbitrarily estimated, and at present taken to be 4 annas an acre) that may fairly be attributed to additional protection given to land formerly under cultivation. This is the plan followed in the tables of the Appendix; it seems to me to be the correct system, and if so, the reference to what are called indirect returns is misleading and had better altogether be left out of these reports. Even however if there were no net profits and if the embankments did no more than pay the interest on the capital expended, the great benefits which they confer on the people would be ample justification for their construction. But financially considered, the scheme is a very hopeful one and there is every reason to believe that it will prove highly remunerative in the course of a year or two. Notwithstanding the large and annually recurring deficit on the two upper sections, the entire deficit on the whole scheme up to the end of 1876-77, was only Rs. 41,752 or 1·6 per cent on the capital outlay of over 25½ lakhs, while there was a net profit of Rs. 51,072 or nearly 2 per cent on the working of the last year.

(*g.*) *Extract from Memorandum by* C. U. AITCHISON, ESQ, C. S. I., *Chief Commissioner of British Burma, on the Chief Engineer's Revenue Report on the Irrawaddy Embankments for 1877-78,—(Dated Rangoon, 23rd January 1879.*

In accordance with the instructions issued on last year's report, the so-called indirect returns, amounting to Rs. 662,262, for which credit used to be taken in estimating the financial results of these embankment schemes, have been very properly thrown out of consideration. The present report deals with direct results only.

2. The report for 1877-78 confirms the decision already expressed that the Kyangheen section of the embankments will never pay; that the Myanoung section also is likely to prove financially a failure; and that it is solely to the to the third or Henzada section that Government must look for remunerative returns. On the Kyangheen section the deficit in 1876-77 was Rs. 890 more than in 1875-76; this year it is, including remissions recommended, Rs. 1,574 more than in 1876-77. There has been no increase in the area brought under cultivation; it is admitted that hardly any is to be looked for. On the other hand, with diminished receipts and an increasing deficit, there was an increased expenditure of Rs. 16,582. The deficit on this section up to date is no less than Rs. 73,608. The annual interest on the capital at 4½ per cent is Rs. 6,124, if the deficit which amounts to more than half the capital be added, the interest would be Rs. 9,437. If every acre which this section of the embankment is designed to protect were fully cultivated and assessed at Rs. 2, the total revenue

would only amount to Rs. 5,356, so that to secure a maximum revenue of Rs. 5,356 (as a matter of fact the increase is only Rs. 1666;) we have incurred expenditure calling for an annual payment in the shape of interest of at the very least Rs. 6,124. These figures seem to show that this section of the work, which no one asserts to have been necessary as a part of the series, ought never to have been undertaken. The argument that the embankment is useful as a road is beside the question in its present aspect.

3. On the Myanoung section the results are not promising. Here the aggregate deficit is Rs. 398,610 including Rs. 11,816 last year, and it is anticipated that this deficit will go on increasing at the rate of Rs. 8,000 or 9,000 a year unless considerable additional outlay is incurred in completing the works and making them perfectly protective. Leaving the deficit out of calculation altogether the interest annually due on the capital outlay at 4½ per cent is Rs. 44,311; including interest on the deficit, it amounts to Rs. 62,248. On the other hand the increased revenue from the works is only Rs. 34,365. If therefore the capital expenditure be largely increased, as it must necessarily be, and the deficit meanwhile go on increasing, as for some years at least it must necessarily do, there is little prospect that this section will ever pay.

4. In the review of last year's report, inquiry was ordered to be made into the causes of the downward tendency of the Myanoung section. It appears from the reports submitted by the Commissioner and the Executive Engineer that not only are the works incomplete but the river is cutting away a considerable portion of the finished embankment and that until complete protection can be afforded it is impossible for the revenue authorities to do anything to induce the extension of cultivation. "One or two miles" the Executive Engineer says "may go; but possibly only half a mile may go; and we can do nothing to stop, nothing to alter this action." This result of having only to wait and watch, is not encouraging.

5. The truth is that the only paying section of the embankment project is the Henzada section. Here, notwithstanding numerous breaches from the unusually heavy floods of last year, there has been a large enough return on the outlay to wipe out the entire deficit on the other sections and leave a small surplus of Rs. 4,814. As the current year has been one of average rainfall and no heavy floods, and not a single breach occurred in the embankment, the next report it is hoped will show a very considerable return.

REPORT

ON THE

IRRAWADDY RIVER

PART I

Hydrography of the Irrawaddy River.

PART II

Hydrology of the Irrawaddy River

WITH APPENDICES

AND

SUPPLEMENTS A. B. & C.

BY

R. GORDON, ESQUIRE, M.I.C.E. & M.I.M.E.

Executive Engineer, Henzada Division.

RANGOON.
PRINTED AT THE P. W. SECRETARIAT PRESS.

1879.

OF THE
BOMBAY
PRESS

REPORT

ON THE

IRRAWADDY RIVER

PART III

Hydraulics of the Irrawaddy

WITH APPENDICES

and Supplement D

BY

R. GORDON ESQUIRE, M. I. C. E. AND M. I. M. E.

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Royal Asiatic Society.
CLASS

ERRATA.

PART III.

Page	4	Line	6	Insert (after "observations") connected with the enquiry. Velocity observations."
„	4	„	6	For was ... Insert were
„	4	„	7	„ was ... „ were.
„	6	„	31	„ end ... „ enquiry.
„	6	„	30	Delete "it will be a great advantage to the special enquiry."
„	7	„	21	For of in ... Insert in of
„	12	„	15	„ imposible „ impossible.
„	12	„	28	„ formuæ ... „ formulæ
„	12	„	37	„ Chausseés „ Chaussées
„	13	„	35	„ varies ... „ vary.
„	14	„	6	„ measurment „ measurement.
„	15	„	28	„ efforts ... „ effects.
„	15	„	33	„ discharge „ discharges.
„	17	„	34	(heading or subject). For depth ... Insert depths.
„	19	(At foot note No. 2.)		For Bemegung ... Insert Bewegung.
„	23	Line	1	Insert (after the word "Appendix") V.
„	22	„	3	For noticable ... Insert noticeable.
„	27	Table	15	„ Maximum minimum mean, Insert max. min. mean.

„	—·64	0·50	0·570	„	—0·50	—0·64	—0·570
„	—·58	0·39	0·485	„	—0·39	—0·58	—0·485
„	—·50	1·04	0·312	„	1·04	—0·50	0·056

„	30	Line	20	„ Fahrenhert... Insert Fahrenheit.
„	35	„		(At foot note No. 2). For Rivers ... Insert River.
„	36	„	14	For Leonardi ... Insert Leonardo.
„	38	„	9	„ regurgilation „ regurgitation.
„	38	(At foot note No. 2.)		For and ... „ und.
„	38	(ditto)		Remove the words "Strasburg 1874" To the end.
„	39	Line	30	(Heading or subject) Insert a (before the word "river.")
„	40	„	80	For here ... Insert there.
„	41	„	40	„ engergy ... „ energy.
„	42	„	55	„ presure ... „ pressure.
„	44	„	7	„ alluvian ... „ alluvion.
„	44	„	24	Delete "of" (after the word moving.)
„	44	(At foot note.)		For to conjiguration Insert la configuration.
„	44	ditto		„ propondure he lan Insert profondure de l'eau.
„	46	Line	35	„ heat producing Insert heat—producing.
„	47	„	13	„ enery ... „ energy.
„	48	(Section IV) Heading)		For Delta General Insert Delta. General.
„	48	Line	13	For out ... Insert cut.
„	48	„	28	„ larger ... „ large.
„	49	„	13	„ latter ... „ later.
„	50	„	24	Delete "to the mouth of the Daga river."
„	56	„	25	For entrace ... Insert entrance.
„	58	„	9	„ considerable „ inconsiderable.
„	59	„	8	„ main ... „ marine.
„	59	„	21	„ when ... „ where.
„	59	„	29	Insert though (before the word "many.")
„	59	„	56	For bottom ... Insert bottoms.
„	60	„	12	„ 180° 8′ ... „ 18° 0′.
„	60	„	32	„ re-stiring ... „ re-stirring.
„	63	„	4	„ runing ... „ running.
„	63	„	13	Delete the (before the word "plains."
„	70	„	18	Delete ! ... Insert (common full stop.)
„	71	„	13	For much ... „ must.

Page	71	Line	15	For are ... Insert is.
„	75	„	8	Insert "in" (between and other.)
„	75			heading of para 133 for "Their" Insert "Third."
„	82	„	48	For stripes ... Insert strips.
„	83	„	28	„ conlusion... „ conclusion.
„	85	„	43	„ vermine ... „ vermin.
„	14	„	27	„ decends ... „ descends.
„	100	„	29	„ laisez ... „ laissez.
„	101	„	22	„ Americen „ American.
„	103	„	48	„ ignortant... „ ignorant.
„	104	„	13	„ occurence „ occurrence.
„	104	„	22	„ in ... „ on.
„	109	„	4	„ site ... „ side.
„	115	„	22	Delete "both „ „ "all the."
„	117	„	46	Insert (a comma after "respects.")
„	122	„	52	Insert , (after the word "bank")
„	123	„	18	For has ... Insert have.
„	124	„	23	„ comparitively „ comparatively.
„	125	Last line		„ increasends „ increased.
„	140	Table	25	„ 1 to 0 ... „ —1 to 0.
„	151	Line	7	„ will be ... „ has been.
„	151	„	17	„ comparitively „ comparatively.
„	156	„	38	„ contigency „ contingency.
„	158	Section X Line		8 For undertean, or leftk Insert undertaken, or left.
„	158	„	„	39 Delete definitivelys Insert definitively.
„	158	„	„	45 For an ... Insert at.
„	„	„	„	46 For proposet „ proposed
„	„	„	„	47 „ inted vals „ intervals.
„	„	„	„	48 „ ir ... „ in.
„	159	„	„	9 „ comparision „ comparison.
„	161	„	„	28 „ difierent „ different.
„	„	„	„	28 „ flood ... „ floods.
„	„	„	„	36 „ come ... „ comes.
„	„	„	„	50 „ excrcise „ exercise.
„	„	„	„	56 „ 25·71 „ 35·71 (under Henzada.)
„	„	„	„	56 „ 26·17 „ 36·17 (under Zaloon.)
„	163	Line	50	For others ... „ other.
„	166	„	1	Insert has (before the word "been.")
„	166	„	33	For though ... Insert through.
„	169	„	29	„ were ... „ where.
„	171	„	24	„ on ... „ and.
„	171	„	50	„ 40 ... „ 30.

Supplement D of Part III.

„	206	Line	2	For have ... Insert has.
„	209	„	26	Insert a (before "length.")

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PART III.

The Hydraulics of the Irrawaddy Delta.

INTRODUCTION.

The origin of the present investigation.

THE original purpose of this enquiry was to investigate the consequences of embanking the Irrawaddy main channel on two sides, from the head of the delta seawards, for a distance of 150 miles. A continuous line of embankments had been designed for the right bank, from the high land to the north of Myanoung to Pantanaw, by Colonel Short, R. E., and this had made a somewhat desultory progress from 1863 to 1867; when Colonel Fraser, R. E., then Chief Engineer of the Province, proposed the second line of embankments from the high land at Talokmoh, opposite Saiktha, to Yandoon on the large branch of the river leading to Rangoon, and a few miles above the Pantanaw branch. It was held that, beside the immediate result of reclaiming a large tract of fertile ground yearly inundated, it would be of material advantage to the Railway then contemplated, and now executed, between Rangoon and Prome. A series of reports (1) from Engineers and Civil Officers acquainted with the country was called for, and, after receiving the comments of the Local Government, was submitted for the consideration of the Government of India. The principal question raised was, could the double embankment proposed, be executed on the same part of the channel of so large a river as the Irrawaddy, for a length of 150 miles, without entailing grave consequences, such as, in the first place, raising the entire surface of the river to a great extent through shutting into it the large quantity of spill water formerly lost over and through the banks, and spread over the country; and, in the second place, subsequently raising the bed of the river continuously, thus necessitating a constant raising of the embankments, with enormous and indefinitely increasing expense and danger to the population. ' Besides this primary question, others relating to the expediency of keeping open the two branches from the Irrawaddy to the Bassein river, and of closing all the minor streams to the Rangoon river; the propriety of undertaking works of irrigation for portions of the country exhausted through continuous over-cultivation; and regarding works for improving the navigation of certain channels of the river, were mooted.

The orders of the Governor General in Council regarding the enquiry.

2. The Governor General in Councilin remarking on the papers (2) pointed out the paucity of facts and data from which conclusions could be drawn; as well as the inexpediency of undertaking works of such magnitude as those proposed, without having first entered into and discussed the whole subject, with a view to devising a general system of embankments for Lower Burma so that their future extension should be carried on in a scientific and systematic way. He ordered the special question raised to be merged into a more general enquiry. "The Governor General in Council is unwilling to assent to the further prosecution of works of this class without first undertaking a thorough investigation into the whole question. It will be necessary to obtain exact data as to the levels of the surface, and the volume of water to be dealt with. The greatest caution will be required in determining the capacity of the river between the embankments to be formed, so as to admit of the proper discharge

(1.)—Reclamation of Waste Land, Reports in 1867-68 and 1868-69.

(2.)—Government of India, letter No. 277 I., dated 8th October 1868.

of the flood waters." The interests of navigation were to be conserved and existing channels improved; especially was it necessary to keep open the large existing branches of the river, and to control rather than to blindly close them. "It would, his Excellency in Council thinks, be almost criminal to disturb the existing condition of the river, only for the purpose of protecting one place at the expense of another." Attention should be given to the possibility of ameliorating the condition of tracts of country by irrigation. "The investigation was to include the main facts relating to the delta of the river, the form of surface and volume of water carried down to the sea through it. A series of cross sections were to be taken every 5 or 10 miles apart, with proper longitudinal and check lines of level. River guages should be put upon the Irrawaddy, and on any other sufficiently important streams, and regular registers kept of the height of the water. Observations of the discharge should be made at varying heights of the water, so as to get the best possible approximation to the whole volume of water passing down the river in all possible states." Permission was given to continue the existing works. "If you consider it desirable, the western embankments might be gradually extended below Henzada as far as Donabyoo or Pantanaw, so long as the embankments are limited to one side of the river, and are not pushed on too fast, the Governor General in Council believes that no great risk will be incurred." It was suggested that if the branch channels to the Bassein river were kept open, this might involve the construction of embankments along them.

Determination of the enquiry into three different courses.

3. These orders lay down the lines on which both the works executed and the enquires in progress have been conducted The enquiry itself was definitely determined into two distinct courses. The one general and far reaching to include all that could be gathered relating to the river, to the floods, to the delta, and to the embankment or other works in the delta considered comprehensively as a system; the other specific and restricted to the paramount object of solving the original problem regarding the probable effects of embanking both sides of the Irrawaddy for 150 miles continuously from the head of the delta. A third branch has within the last two years been opened up for enquiry, which has become of far more pressing and immediate practical interest than either of the others; and which has tended to absorb the attention from them. It arose out of the permission to continue the progress of the existing works, and from the carrying out of this on the suggestion to embank the side of the branch leading to the Bassein river. This report is written principally with the object of elucidating this branch of the enquiry; but it is intended to include all that has been gathered on the general question and to exclude and delay for the present the consideration of the prediction of the effects of the double embankment on the Irrawaddy. The reasons for this will be best understood from the course taken by the different enquiries and their present position.

Colonel Stoddard's investigation.

4. In the orders of the Government of India it was recognised that only special studies carried on for some time could make any progress with the vast subject of enquiry opened. An officer experienced in Hydraulic works on large deltaic rivers was selected and deputed to conduct the enquiry. Colonel Stoddard, with two assistants and a subordinate staff, commenced the necessary observations towards the end of March 1869. A series of levels was taken from Prome to Myanoung, and one cross section of the river at Myanoung, with another at Prome. Some measurements of the discharge at mean flood were made at the latter place. At this time the practical charge of the works was in the hands of the present writer, who, early in 1869, established guages at some of the stations on the Irrawaddy from Myanoung southwards. These have subsequently been extended with the progress of the works. While Colonel Stoddard was taking the river discharge at Prome, Mr. Wallnutt, Assistant Engineer, and the writer took similar measurements at Henzada. These were not available in time for Colonel Stoddard, who was leaving the province in September 1869, and who sent in a report (dated 14th September) on his operations. These had

been conducted almost exclusively at the head, or to the north of the head of the delta, and though excellent in themselves, and involving much personal exposure in their acquisition, were inadequate to deal with either the general or the special question before him. The Government of India in acknowledging (1) his report stated "that the information afforded is both interesting and valuable, and the surveys executed will, no doubt, be of service to the local authorities though far from sufficient to form the basis of a project such as the Government of India desire." Colonel Stoddard's work and attention had been principally directed to the specific problem of the probable rise of surface due to the double embankments; and on this point he concluded "*that the extra rise caused by leveeing the river on both sides throughout the Delta, will not exceed the average of one foot.*" Commenting on this and on the reasons given for it, the letter of the Government of India last quoted says:—"There would thus seem reason to conclude that longitudinal embankments along the whole distance would have the effect of raising the surface at Henzada between three and four feet instead of one foot." The writer was ordered to take charge of the different investigations on Colonel Stoddard leaving, in addition to the practical charge of the works. In doing so, he examined the data and conclusions of Colonel Stoddard in a report then submitted, in which he found that by applying the method and formulæ devised by Generals Humphrey and Abbot for the Mississippi to the Irrawaddy data gathered at Prome and at Henzada, a possible rise might be expected at Henzada from embanking the river of from 7 to 12 feet. It was, however, at the same time pointed out that the data were unsatisfactory and the results inconclusive. This closed the first stage of the enquiry.

Results of the first stage of the enquiry.

5. A second stage was occupied by a wholly new branch of investigation. A financial crisis occurred in 1869, and many of the great works in progress in India were placed upon their trial, and those responsible for them were compelled to put forward a justification for their existence either as works corresponding to some urgent economic need of the country, or as likely to be financially reproductive in themselves. The Irrawaddy embankments had been sanctioned and permitted to proceed upon both grounds. The continued local disasters from high rises of the Irrawaddy in certain cultivated tracts on the right bank of the river had given the first stimulus to the undertaking of protective works, and exaggerated estimates of profits had been seriously offered and formed the basis on which sanction had been asked and accorded to them. The Myanoung embankment, for instance, was calculated to yield a profit of from 21 to 30 per cent on the outlay. These hopes proved fallacious, as at that time and up to the present it has not even paid interest on the money expended on it. The Government of India rejected the assumptions and conclusions offered, and demanded that, before any further works should be undertaken, a sound financial basis should be found for the whole scheme. The drawing up of a statement showing the economic and, in some manner, the financial reasons for the existence and extension of the embankment works, fell into the hands of the writer early in 1870, and on the 10th July of the same year it was submitted (2). The statement was wholly adopted by the Local Government, and made the basis of its claims for a continuance of the works. It was accepted partially by the Government of India, and finally approved of in its entirety by the Secretary of State for India. Sanction was accorded to the resumption of the works, which were recommenced at the end of 1871.

Second stage of the investigation.

A fourth branch of enquiry opened.

Suspension and resumption of the works.

6. These had been wholly suspended in the interval. The opportunity was favorable for prosecuting a scientific investigation; but this also was stopped, and all expenditure upon it absolutely prohibited. The river gauges on the Irrawaddy and Bassein rivers

Delay and restriction of the prosecution of the enquiry.

(1.)—Government of India letter No. 355 I., dated 25th August 1870.

(2.)—Report to accompany Financial Statement of the Irrawaddy Embankment works, 1870.

were kept up and some longitudinal levels made in connection with the existing works, which were also useful to the enquiry; with these exceptions no observations of any kind could be made. The separate staff for the Delta Survey was removed, and the establishment on the works reduced to the lowest limit. It has ever since been kept down low. It was not till July 1872 that any attempt could be made to resume the observations for the discharge of the river was then instituted at Saiktha the head of the delta, and was continued till September 1873. Other measurements were made simultaneously at Zaloon, 110 miles lower down on the main channel; and at Thabingyo on the Bassein river, just below where the two branches from the Irrawaddy unite. They were continuous at the latter stations during high floods, and intermittent during the dry season. Longitudinal levels and surveys on the site of the proposed eastern embankment were made from Taloukmoh to Mengyee, some 28 miles; and a compass survey of the river channel in 1872-73. But all further observations were suspended for two years from the middle of 1873 till July 1875, while the writer was on furlough.

Theoretical enquiries added to the practical ones.

7. Besides the observations made on the river itself there are two other modes in which the objects of enquiry, more particularly the special one, can be assisted. One is by ascertaining how far the experience of other enquirers on similar works can be made applicable to the solution of the problems presented. The other is by ascertaining how far hydraulic science in its present state can aid by *a priori* method to predict the results arising from the execution of such works. In pursuance of these purposes the writer has for several years devoted time and trouble to the collection and study of works on hydraulics, and has acquired one of the most complete and extensive libraries on the most specialized branches of it ever gathered together; which has been supplemented by reference to works in other libraries. As *ad interim* results of this study he issued in 1873 a paper on the formulæ for the flow of water in open channels (1); and in 1875 one on the theory of the flow of water in open channels (2). These gave, from different sides of the same subject, some of the conclusions deducible from the works of the highest authorities. As a rule it may be said that, while no general solution has been arrived at either by *a priori* or empirical methods for the problems raised by the embanking of rivers, most valuable experience, often dearly purchased, is available on almost every case likely to arise, but which can only be fully utilized after a close consideration and comparison of the details of each work. As to hydraulic science itself, at first sight it seems at present in a hopeless state of confusion, whether we look to it for the expression of known facts by general formulæ, or as the embodiment of a series of deductions from universally admitted principles, by which such cases as arise in practice can be reasoned upon before hand. There is an acknowledgement of this state of the science by the most eminent of recent writers, quotations from whom to this effect will shortly be given. The purpose of the two papers above mentioned was not only to present an exposition of this confusion, but to suggest a remedy for it. The writer believes that this is to be found in reconciling the views of two widely differing schools of hydraulicians; one of which, having no modern representatives, held that the flow of water in open streams depends principally on the pressure of the upper parts of the water upon the lower and little, or not at all, upon the surface slope of the stream. The other school which, until late years, was almost universally prevalent, considers that the flow is entirely due to the surface slope; and that the pressure has no influence. The latter view, which dates from the time of Du Buat, about a century ago, has had eminent dissidients throughout; and these have lately increased in number; but difficulty has been experienced in finding a principle to take the place of Du Buats in explaining the flow of water. The two views are as opposed to each other as those of the Ptolemaic and Copernican schools regarding the motion of the earth and the sun relative to each other.

(1.)—On a new formulæ for the flow of water in open channels 1873.

(2.)—On the theory of the flow of water in open channels 1875.

And if we could suppose our earth, instead of being a planet indefinitely smaller than our sun, to be one of a pair of double suns such as are known to exist in the heavens, the views both of ptolemaists and copernicans would have a certain validity, provided they did not exclude the possibility of their opponents view being correct. Both would be possessors of half the truth and by joining their views the true explanation of the double sun system would be found. In the same manner, in hydraulics, a full explanation of the flow of water in open channels is to be obtained by combining the views of the opposing schools. A river runs owing to both pressure and surface slope. It is necessary to have some principle to start from to obtain anything like a scientific basis for proceeding, so as to combine the valuable experiences obtained in varying conditions on numerous watercourses into a systematic whole; and by the adoption of the principle suggested, as a working hypothesis, there is reason to hope that it will be practically useful, and possibly, eventually, have its existence justified by theoretical proof. In the mean time working formulæ have been derived from it by which it is possible to combine the most varied experiments on the small artificial channels of M. M. Darcy and Bazin with those of all sizes of natural rivers up to the Mississippi and the Irrawaddy. It has been shown that the latest and most extensive and accurate experiments favor the views held of the combined operation of pressure and surface slope in promoting flow, and it is possible to bring forward still further proof. The Mississippi and Irrawaddy experiments in particular have been adduced in the above papers; and the elaborate experiments of M. Bazin, and of Captain Cunningham R. E, in India, are available to give it still further support. The papers themselves and the views advanced have been received with favorable consideration by some of the most pre-eminent writers on the science in different countries; and material assistance has been given to the writer; particularly by Signor Lombardini of Milan; by M. Bazin of the Ponts et Chaussées of France, who, besides reducing a considerable number of the Irrawaddy observations, has published a paper upon them (subsequently translated by Captain Cunningham); by General Abbot in America, who has aided by counsel and by kindly supplying the professional publications of the United States Government; and by others, who, by friendly criticism, have offered the utmost encouragement to proceed with the developement of the ideas put forward. In this last category must be mentioned Herr Professor Bornemann, whose paper in the Civilingenieur of 1877 enters into the writers views at length with distinct approval. In every case, however, judgement has been more or less suspended, as both the writer and the eminent specialists who have favored him with their opinions hold that much further must be done before the new combined principle can in any sense rank higher than a speculative or a working hypothesis. It was necessary to give some slight description of the nature and position of the views advanced in those papers, as they have been circulated on the understanding that they were to form part of the report in preparation on the Irrawaddy Embankment Works; and it is now intended formally to exclude them from detailed consideration in the present report. The sole reason for this is, that it has been found incompatible with the nature and scope of this report to include the more purely technical details on such a scale as, in justice to the more specialized enquiry, they must enter, when this is discussed.

Completion of all the field operations necessary for the enquiry.

8. The materials gathered for the purposes of that enquiry are immense and almost beyond precedent. The whole of the observations ordered are now completed. The gauges have been recorded steadily at an increasing number of stations for the last 10 years. The measurements of velocity and discharge, which already in 1873 out-numbered all such on other rivers, have been extended by similar ones during the flood season of 1875; and on the Nawoon by others in the present year. Cross sections of the river throughout the portion of the channel to be embanked have been taken about every 4 miles and have been connected by a theodolite triangulation and survey of the channel as well as by levels. The slope of the river surface has been carefully determined for all stages of the river both by the longitudinal levels, and by carefully ad-

justed guages in sets of 5 and 6 each, one mile asunder, 3 on each bank at Saiktha and at Myanoung. The site for the proposed eastern embankment has been cleared of jungle, surveyed and levelled, with cross sections to the inner country; and all the maps, plans and levels have been got out preparatory to determining the height of the new work. All that it has been possible to do in the field and most of the office work preliminary to the final determination of the height the surface of the river will be raised has been done. But to pass from the known facts and data of the Irrawaddy and of similar rivers to the prediction of the as yet unknown results of the proposed works, is a most difficult and serious step. So long as there is no pressing necessity for coming to a conclusion there is every prospect of advantage from not doing so prematurely. It is by no means difficult to obtain an answer to the question put as to the height the water will be raised. Nine years ago Colonel Stoddard answered it for the Irrawaddy. The river surface was only to be raised one foot throughout. From the same data, or want of data, the professional adviser to the Government of India deduced that it would rise 3 or 4 feet at Henzada. The writer, with a little additional data, inferred that it would be raised from 7 feet to 12 feet at the same place. But offhand answers on speculative grounds will not suffice. The consequences are too grave for a task of this kind to be lightly undertaken. It is not the first cost alone that has to be considered, though this must be in the present case, at least £200,000 or £300,000. To make the work too light may entail serious disaster. A moderate increase of height will double the cost. The land will be taken up by cultivators immediately, almost before the works are finished. When the surveys were in progress numerous plots were marked out in anticipation. It is well known to be the most fertile and the most favorably situated land in the province. It will be rushed by the people till none is left unoccupied; and any subsequent disaster will thus entail the more suffering.

Exclusion of the special problem of double embankments for the Irrawaddy from the present report.

9. The range of the observations made for the special enquiry regarding this particular work covers in part that required for the general investigation ordered. It will thus be a great advantage for the special end to have the broader results obtained for it grouped together from the general point of view preliminary to discussing them finally, and it will be a great advantage to the special enquiry to have all the more general questions removed from the field of discussion before this is accosted, so that it can narrowed down to the purely technical grounds, uncomplicated by other considerations. The work itself can not in any case be put in hand properly until some great changes at present in progress on the river near the great bend at Thambyading are worked out. And it will for many reasons be advisable to wait till the works now in progress on the western side of the Irrawaddy and the Nawoon river are finished, or nearly so, before commencing the new ones.

The prosecution and progress of the Henzada Embankment.

10. The older works have been carried out under the permission granted by the Governor General in Council in 1869. It was then contemplated that, as they were only executed on one side of the river no risk or questions of a similar kind to that raised for the double embankment would be met. But it has happened that the suggestion given in the same orders, to embank one side of the Nawoon or Bassein river in conjunction with the Irrawaddy works, has entailed the very risk sought to be avoided, has raised the same question, but in a different manner, and has provided a solution at some cost, but with, on the whole, no unfortunate results. It is well known to every Engineer that no works of the kind yet executed in the world have achieved success without having had to undergo a period of trial and proof, and that as no *a priori* solutions of the problem have ever been furnished, the system of tentative efforts has always been adopted. The embankment on the left bank of the Nawoon has gradually been extended, year by year, until it has reached and passed a part where spurs from the Arracan hills come down on the opposite bank, and close in on the river channel; acting precisely as a double embankment would do by preventing all further spill or spread of the water. It was hoped, by great caution, and

Its Nawoon branch raises and solves the problems of double embankments.

very slow extension of the works and by making allowance for the expected rise, on the lower parts, to carry out this Nawoon embankment to completion without waiting for the results of the general or special investigation ordered. There was every inducement to go on with the work. The Henzada embankment of which it formed a part has proved a financial success. It had vindicated the predictions made in the statement of 1870; and had not only paid profit, &c., on its own cost, but was likely to clear the deficits on the other works. The mileage rate of the work was much less than that of the older works; and the area reclaimed for each mile of extension much greater. The work had proved itself sufficiently strong to withstand the severe tests of the great flood of 1875, while all the other parts failed. There was then justification for proceeding with the work; and sanction had been accorded to it. Unfortunately an exceedingly heavy local flood came down the Nawoon in 1876, just as the new works reached the part where the hills meet the river. The softer portions of the embankment gave way. Little damage was done, as the newly reclaimed land was not fully settled. It was doubly unfortunate that all the funds for the year had been spent before this took place, as the works could not be properly strengthened in the weaker places before the great 1877 flood came. This severely tested the whole embankment system. Some of the older works were breached. The double effect of the elevation of the river surface through the entire closing of in the river, and the local floods on the Nawoon itself, came into play and destroyed large portions of the newer embankment works. The damage was not very great and no lives were lost. Since the flood all the damage has been repaired, the works strengthened and raised; and the problem of double embankments, or their equivalents, solved as far as the Nawoon is concerned. There has been a permanent raising of the surface at one part of nearly 4 feet. In other places it is less, diminishing to nothing or nearly nothing above and below. A detailed and specific statement of all the attendant circumstances must be of the very highest value to the subsequent enquiry for the Irrawaddy. This then will prove a part of the present Report.

A detailed description of the Nawoon Embankment necessary.

11. Another and more practical reason why the account must enter here into the fullest detail is, the Government of India has suspended all further progress on the present works both until the results of the general enquiry have been submitted, and until it has been fully shown that these works themselves can be continued without undue risk from the changes they are bringing about, and from the changes taking place on the river itself, and likely to affect them. Special reports have from time to time been submitted on the works in progress and on the results of the floods; but the Government has finally rejected them as being too limited in their scope and as possibly misleading through presenting for consideration only the series of incidents falling immediately within the field of greatest interest without subordinating these duly to other probably more important changes. Of these changes perhaps the most noticeable is the great bend of the river at Thambyading, at the head of the two branches to the Bassien river, which has undergone a succession of variations which seemed likely at one time to result in turning the main channel of the Irrawaddy down to Bassein. Fortunately all local apprehensions on this head have subsided and are occasionally lost sight of; but the whole history of the circumstances requires to be given to show the reasons for this.

The work has been suspended until this Report has been received.

12. The programme of this Report has thus been determined partly by the orders given, partly by the nature of the information available on the subject, and partly by the exigencies of the works. In attempting to deal with a description of the river and its floods the vexed question of the geography of its upper sources had fairly to be met. That this is not in a more satisfactory condition is solely due to Officers of the Government of India, who have, by their authority alone, upset the previously existing notions, based on evidence of a high class, without substituting other equally definite notions, based on sufficient evidence and congruous amongst

Programme of the present Report.

themselves and with known facts. The utmost confusion is discernible, some eight or ten different versions of the connection of the rivers of Thibet being given by official authority with the rivers of Farther India. The meteorology on which the explanation of the floods depend is, as yet, in an equally unsatisfactory state. It has thus been necessary to treat both these branches of the enquiry in the fullest manner in the two preceding parts of the Report, with the hope of eliciting further information on both heads. The facts about the delta, the floods as they appear in it, and the changes in progress or required are better known; and by leaving the purely technical details to be critically discussed in connection with the special branches of the enquiry they concern, the more general points can be more concisely dealt with. These will form the third part of the Report. The existing works require a fuller description of their present character and anticipated results both with a view of obtaining sanction to their further extension and with the aim of aiding in some measure to the discussion afterwards to be held on the difficult question of embanking both sides of the Irrawaddy main channel.

SECTION 1.

The discharge of the Irrawaddy through the Delta.

13. The principal measuring station of the discharge of the Irrawaddy was established at the village of Saiktha. It is situated at the lowest part of the course of the river where the waters are entirely contained within the river channel and have not begun to flow over the bank to find an independent course to the sea. A small double range of hills and undulating ground runs north and south on the opposite bank, from Prome to Talokmoh, the place where a Chinese army halted in its pursuit of the Burmese King in the thirteenth century. This elevated ground effectually shuts off all communication from the Irrawaddy to the low valley of the Hline, which stretches from the east of Prome southward to Rangoon; but it is said that formerly there was a separate channel of discharge from the Irrawaddy to the Hline to the north of these hills through the site of Prome itself. The Nawing, a large stream from the Pegu Yoma, enters the Irrawaddy at this spot. It is some 200 feet wide and 15 to 20 deep. In high flood it spreads over the banks, and the spill drains down the Hline; but the Irrawaddy water rarely if ever finds its way by this course at present. The drainage from the western slope of the hills south of Prome flows into the Irrawaddy; but south of Talokmoh no additions are made to its discharge from the country on the eastern bank.

The head of the Irrawaddy Delta, East-side.

14. On the west side of the Irrawaddy the country to the south of Saiktha is occupied by a network of small spurs diverging from the Arracan Yoma, and from a large branch of the same, which abuts on the river in a nearly perpendicular rock at Akouk-toung, half way between Prome and Myanoung. These hills preclude all escape of water from the Irrawaddy as far south as the Patashin Choung (Choung= stream, Burmese.) Between this and a small area of elevated ground below Myanoung, a low portion of bank permitted a large discharge in floods which inundated the ground behind Myanoung, and found its way by the Bassein river to the sea. This is now closed by the Myanoung Embankment. The head of the delta is thus some ten miles lower on the right bank than on the left, the interval between Saiktha and Myanoung receiving the Patashin and smaller streams draining nearly 400 square miles of hilly country into the Irrawaddy. It would have been desirable to include this in the measured discharge; and if it had been possible to establish the measuring station at Myanoung this would have been done; and the quantity lost during floods to the Hline between Talokmoh and the station approximately estimated. But from Saiktha southwards for very many miles the river occupies one principal and several smaller channels, constantly changing section. At Myanoung the river bed is from bank to bank over three miles wide (see Plate); the principal channel being only 4,300 feet in width; and the water in flood coming through other irregular channels on the east bank. It was thus difficult, if not impossible, to include the Patashin discharge in the measurements. It may be roughly estimated from the size of the channel which is about 220 feet wide by 20 deep; and is thus capable of carrying 30,000 to 40,000 cubic feet per second in flood. Some approximation to the varying discharge must be made when considering the double embankment; but it has so small a proportion to the total discharge of the Irrawaddy that it can be now neglected.

Delta West side.

15. The selection of Saiktha was decided on after a careful examination and survey of the channel for several miles. The reach of the river here is open and free from islands; and, though not straight, is gently curved, with well defined banks and regular bed, enclosed by hard unchanging banks, where the current is most disposed to act. It has thus preserved its contour without great changes for several years. The actual cross section of the river from which the measurements of discharge were to be taken was fixed in the following manner, both here and at all the measuring stations. A long base line was marked out on the elevated bank, the longest possible the ground permitted under a quarter of a mile, as the river is about a mile in width. In the case of Saiktha one could not be obtained over 800 feet, on account of obstacles and irregular ground. From the ends of this, two parallel section lines were set out across the river as normal to the current as the eye could judge. Surface floats were thrown into the water from a boat above the higher section line, and observers with theodolites at the ends of the base line carefully noted the positions at which these floats crossed the two sections. A plot was made on a large scale, when a sufficient number of such observations had been taken all across the river, shewing the survey of the river channel, the base line, the section lines, and the paths of the floats across these. It was found that these paths were more or less parallel to the line of the maximum velocity of current, corresponding nearly to the *thalweg* or line of greatest depth of channel; but curious and inexplicable divergencies sometimes occurred, when a single float would pass diagonally across the paths of other floats. Similar experiences were obtained on other sections, and on other occasions at the same place. It is possible that in some cases the divergence may be due to a wrong observation at one theodolite; but in others this could not explain it, and it is probably due to a submerged eddy catching the float and taking it out of the common direction. In finally selecting the cross section no notice was taken of these wandering floats. A line was struck on the plan which, as accurately as possible, lay normal to the general direction of the paths of the floats across the two sections. This was then taken and set out upon the ground; and a cross section of the river carefully taken upon it.

The selection of a measuring Station for river discharge at Saiktha.

16. The same observers took a new base line one end of which coincided with the section line chosen. A third observer in a boat carefully took the depth on this section line as the boat was allowed to drift over it. The position of each observation was fixed with the theodolites. A common sounding lead and line was used for taking the depth, which was accurately noted. A large number of observations was made over the whole section line. Levels were taken from a masonry bench mark on the bank to the water edge before and after the soundings. A gauge was fixed close to the end of the section line upon which the variations of river level were duly read and recorded. The whole of the soundings taken were plotted on a large scale; and as they were at somewhat irregular intervals apart, regularly spaced lines were interpolated and measured, and from these the calculations of the area of the cross section were made. This gave the area only for the day or days on which the soundings were taken, but very slight additional work gave the cross section of the stream for each height of the gauge read in the oscillations of the river surface from day to day. It is obvious that if a rule were known from which the mean velocity of the water on each area of the cross section calculated could be found, the total discharge of water on each day could be readily obtained. The chief aim of hydraulic science for centuries past has been to devise rules and formulæ and methods of procedure to obtain such knowledge at the least possible expenditure of money and labour.

Method of taking the Section.

17. The modes by which it has been attempted to ascertain the discharge of streams of water can be classified under three heads:—1st, by rules founded on *a priori* principles from which, if one definite velocity, as the maximum velocity of a stream is known, the velocities at other points, and the mean velocity,

Different modes of calculating the discharges of a river.

can be deduced; 2nd, by formulæ, based solely on experiential or empirical data, derived from measurements made on certain streams, and which were, in a measure, independent of *a priori* principles:—3rd, by actual measurements through instrumental observations, made on each stream on each occasion when it is required to ascertain the discharge. The Engineer, who has need to deal with the discharges of rivers, must recur to one or other of these modes to ascertain the amount of discharge.

Reasons for applying the most costly and difficult mode.

18. The complexity and difficulty as well as the cost of applying the above modes increase in the order given, so that if they were equally valid there would be no reason to prefer the third to the second or this to the first. And as, after due deliberation, the most expensive and elaborate system has been employed upon the Irrawaddy, some testimony of independent authority regarding the value of the former methods will be given as a justification for this course; and afterwards some of the results established will be briefly indicated.

The *a priori* method of calculation.

19. If all the parts of a current ran with the same velocity it would be sufficient to measure this at any point, and, multiplying the area of the cross section by the result, obtain the discharge with accuracy. The commonest experience proves that there is no such equality of velocities. The centre of the surface of a stream is often seen to flow faster than the sides. The law of the changes has been sought and various solutions given. It has further been assumed that there is a fixed relation between the velocities in the surface of a stream and those at points vertically below. The law of change here also has been assumed to be the same for all streams, and to depend on one or other of two principles. Guglielmini is the representative of a school in hydraulics founded on the application of the one principle. In an early work (1) he assumed that the flow of water in an open channel depends mostly upon the pressure of the upper layers upon the lower, which are constrained to move faster than they would otherwise do. The velocities from the surface to the bottom of a stream thus increase in the same ratio observed in water issuing from holes at the same depths in the sides of a cistern; that is as the ordinates of a parabola, or as the square root of the depth. He afterwards (2) modified his views somewhat, having found by experiment that this law of increase did not always hold good, but maintained his principle, while he explained the differences by the retarding effects of the bed and banks, which changed the order of the flow. Other exponents of his school, however, held the original views and based practical rules upon them, which in one case given, furnished a discharge over 100 times greater than the actual result (3). The erroneousness of these rules came to be recognised, and finally Du Buat brought forward new ones (4). He asserted that the old ones had been based on a strange mistake; that the principle ascribing the flow of water to pressure was certainly wrong; and that this was due to surface slope alone. He stated that the force acting on any moving particle in a stream was the difference of pressure of the vertical column in front from that behind; and that as this difference was the same for every particle in the stream when the surface slope was uniform, the whole current tended to move uniformly with equal velocities from top to bottom. As the retarding effect on a stream always arises from the friction of the banks and bed he stated that the velocities near these are always the slowest and those of the centre of the surface always the greatest. He assumed that every channel is lined with a coating of stationary water on which the moving current glides; and that thus, no matter what the substance or condition of a channel might be, the velocities varied on all streams according to the same law of discharge. He attempted to determine this law by experiments on small artificial channels a few inches in depth; and embodied the results in general formulæ, which have been accepted by hydraulicians till within the last few years.

(1 and 2.) Guglielmini. Domenico. De aquarum fluentium mensura. Della natura de Fium.
(3). Grandi le Pere, Del Movimento del Acque. Raccolta Vol: IV, Chap V, P. iii.
(4). Du Buat. M. Principes d' Hydraulique 1816 p. XI and p. 10.

20. These rules have broken down as utterly, though not quite so wide of the truth, as those of his predecessors. A note of warning was sounded by Baron DeProny (1) when developing and improving the rules and the formulæ. He stated out the principles, and, on reviewing them closely, concluded that the examination gave rise to a "suspicion of some *lacune* in the series of facts by which the uniform movement was explained" and he also points out that the material of which the lining consists may exercise influence on the flow (p. 54). M. Navier, one of the ablest writers on analytical hydraulics, says (2) "the pressure at any point whatever of a current of water where the movement is uniform the slope and section constant, is always due to the vertical distance of the point from the surface of the fluid as if the water was stationary. It is by error that Du Buat admits another principle." Here is an explicit upholding of the older principle against Du Buat's. It will be sufficient to give two other extracts from writings of other eminent countrymen of his to show that it is imposible any longer to place reliance on his principle or on the rules deduced from it. Reference has already been made to the elaborate researches of M. M. Darcy and Bazin on the flow of water; and these must always enter into consideration in any discussion of the subject. Their labors, in common with the experiments of Messrs. Humphreys and Abbot carried out on the Mississippi, mark out a new era in experimental hydraulics. General Morin, in presenting the last large work of M. Bazin to the academy of sciences, after a careful review of the results achieved, said (3) "it is seen by the detailed analysis we have made of the memoir of M. Bazin that the nature of the channel lining exerts an influence which cannot be neglected in the resistance it offers to the movement of the water, as done by Prony Eytelwein and all the hydraulicians who have given practical rules on the subject, and that this influence varies so from one lining to another, that it is not possible to represent by one formulæ all the cases that practice offers. Many geometers have sought in later times, by the aid of more or less ingenious hypotheses, to subject all these questions to the calculus; but as these hypotheses were only incompletely conformed to the true circumstances of the movement of liquids, the consequences to which the analysis has conducted them are not found in accord with observation even in the case of uniform movement. The engineer who has need of rules for guidance in his applications, is forced to recur to observations and to content himself with empirical formulæ to represent the results." M. Victor Fournie, also of the Ponts et Chausseés of France, published a resume of the results obtained by Generals Humphreys and Abbot on the Mississippi; and noticed those of M. Bazin. He concludes thus (4). "In the critical study that precedes no conjectural views have been permitted. In these questions all hypothesis is dangerous and it needs to recur to experience. The principles promulgated by Du Buat and developed by Prony are reversed by later studies: this should be. But the methods of these great men remain, and thus the task of the new comers will be more easy. It is meantime necessary that the way be cleared and that the teaching of hydraulics cease to dally with erroneous enunciations which shackle all progress. It needs that young engineers learn that we know nothing of the hydraulics of streams of water, except that the application of the usual formulæ conducts to results known to be false and that the formulæ themselves have no foundation."

Testimony quoted against the use of a *priori* formulæ for streams.

21. The formulæ to which allusion is here made were mostly founded on the principles advanced by Du Buat. Experimental research had a limited share in their formation; and had been used only on a small scale in determining the numerical coefficients of the various formulæ. Thus Prony used a little more than 36 experiments of Du Buat on very small channels. Eytelwein added 56 observations of German hydraulicians, some of which have since been

Erroneous views on the effect of the lining of beds of streams.

(1.) De Prony. Recherches Physico Mathematiques 1804 p 43.

(2.) Navier M. L, applications de la Mecanique 1839 p 403.

(3.) Morin General. Report to Academy of Sciences on M. Baizins's Hydraulic Researches.

(4.) Fournie, M. Victor. Résumé des Expériences Hydrauliques fur la Mississippi 1867 p. 127,

unfavorably criticised. Upon these, and a very few others, all the formulæ used until about the year 1860 were based. Nearly up to this period the principle Hydraulicians had accepted without proper verification Du Buat's statement that water glided on itself in pipes and open streams, and that its flow was thus independent of the nature of the lining. In England this question acquired much notice from practical men in connexion with the proposed drainage of London, between 1840 and 1850. It was advocated that a very economical system of drainage might be employed saving £500,000 to £1,000,000 in first cost of sewers &c., by employing very smooth and round pipes which would permit a larger quantity of water to flow through them, than rough ones in similar conditions. Testimony to this effect was given before the Metropolition Sanitary Commission in 1848; and experiments to determine this point were carried out by the order of Government from 1847 to 1856. The results of the experiments showed that this was the case; that glass and smoothly glazed pipes could discharge 15 to 20 per cent. more than rough ones of the same size; and that the nature of the lining had important influence on the results. These results were rejected by the highest professional authorities at that time on the ground that the experiments were incomplete and unsatisfactory; and the more expensive plan providing large pipes and sewers for the drainage of the Metropolis was adopted. Practically the latter views were right, as the liquids carried, necessarily deposit matter in the sewers, which constitutes the true lining of the channel in which it flows. But the opponents had certainly made out a sufficient case to justify further tests being applied. Had this been done the honor of establishing a most important principle would have been due to English practicians. As it was, it fell to French engineers. M. Darcy of the Ponts et Chausseés of France, undertook in 1850 a series of experiments on pipes, the results of which, published in 1857, clearly proved that so far as closed channels such as pipes, sewers &c. are concerned, the nature of the lining exercises most important influence. He further instituted experiments on open channels, which were carried on, and the results made public in 1865, by M. Bazin. These show that here also the effects, from the same causes, are immense. The older formulæ from their limited scope, and from the narrow principles in which they were based, scarcely allowed the possibility of variation. From one to another their principal numerical coefficients varied in the proportion of 300 to 400. M. Bazin shows that these varies in the results given by the experimental channels, from 130 to over 2500. The consequent error in the results of the formulæ was immense.

Practical errors resulting from use of these formulæ.

22. They have proved equally delusive when applied to channels in earth, or natural water courses. The experiments conducted by Generals Humphreys and Abbot on various channels, ranging from small canals to the great river Mississippi, were intended to test the general applicability of the older formulæ as well as of new ones devised by them. Thirteen of the former were selected for comparison. All these proved totally untrustworthy. The final conclusion was that the tests "establish beyond reasonable doubt, first that the same laws govern the flow of water in the largest river and in the smallest streams; second, that the new formulæ truly express those laws; and third, that the formulæ heretofore proposed do not express them even approximately." The investigations of these writers, and of Darcy and Bazin mark out a new era of experimental hydraulics. Their work gave a new impetus to enquiry, and numerous experiments have since been made in varied conditions, to acquire fresh data, and test the value of the newer formulæ. The older ones have been universally condemned by all. There is no redeeming feature about them, and no justification for their use at present. They may give results varying from $\frac{1}{3}$ to 3 times the true discharge of streams; and any works executed from the results of calculations by these formulæ may err in the same manner, by being wholly insufficient for the required purpose, or by entailing an excessive and unnecessary cost. It is necessary that this should be brought to notice and placed on

Absolute condemnation of the older formulæ for river discharge.

record, as formulæ of the same kind are furnished by high authority under Government, as the proper ones to work from; and the most serious results, entailing disaster and enormous expense may follow from their use. They should be absolutely prohibited from practical use under any circumstances whatever.

Necessity of using formulæ.

23. Even if actual measurment is practicable in most circumstances, for the discharges of streams, there are occasions when recourse must be had to formulæ to assist in extending the calculations, Thus though on the Irrawaddy the most elaborate measurements of discharge were made simultaneously at Saiktha and Zaloon on the main channel and at Thabingyo on the Nawoon, it is desired to know the discharge at other points of the channel at the same time. The cost of measuring is great, and a large trained establishment is required. It is difficult to extend the actual measurement to all the places required. Formulæ embodying the results of the observations made can be extended to apply to the other localities. They are thus an absolute necessity of engineering practice, and some one must be selected or constructed for use.

The modern experimental formulæ and their tests.

Besides the formulæ given by Humphreys and Abbot and those of M. Bazin, several new ones have been devised from their observations and those published for other rivers and channels. The most notable of these are the formulæ of Dr. Hagen of Berlin, of M. Gauckler of the Ponts et Chausseés of France and of Messrs. Ganguillet and Kutter of Berne. In almost every case all connection of the formulæ with theoretical principles is repudiated. Publications of the testing of calculations from these with the measured results of numerous stream discharges have been made. In many cases when the formulæ are applied to rivers or canals in similar conditions to those in which the observations on which the formulæ are founded were made the results agree closely; but it has been found necessary in most cases to give several sets of formulæ to meet varying conditions. Thus Bazin gives four different ones, and Ganguillet and Kutter 12. Even with this extension, unless the whole of the conditions of the stream to be measured be closely similar to those from which each formula has been derived, great uncertainty remains as to the accuracy of the results; and nothing can be known beforehand. Where great care is taken, some of those formulæ may be applied to regular canals and to small rivers with good results. But none is capable of application to the Irrawaddy without previous testing.

The Mississippi formula and Colonel Stoddard's experiments on the Irrawaddy.

24. Colonel Stoddard in his report tried the Mississippi formulæ and came to very favorable conclusions about them. He states that after obtaining the flood discharge by measurement he compared these with the results furnished by the formulæ of Du Buat, of Eytelwein, and of Mr. Neville. He proved that these all gave results "far short of the truth." These are some of the older formulæ before described. He then tested the Mississippi one. He found the actual discharge to be 1,312,750 cubic feet per second at Prome on 25th August; the discharge computed from the last formula being 1,300,900 cubic feet or within one per cent. If the formula could be relied on to always give such results, no direct measurement of the Irrawaddy would be necessary. On examining Colonel Stoddard's results in a former report the writer however found that a serious mistake in the slope of the river entered into the calculation. Colonel Stoddard levelled between two pegs driven even with the water surface on the left bank, 2240 feet apart, and found the slope less than 3 inches per mile. He took this to be the general surface slope of the river and used it in the calculation. Now Colonel Stoddard's own levels over a length of 50 miles showed a fall of over 20 feet in that distance or 5 inches per mile. This, other levels have shown to be about the ordinary slope of mean flood surface. The discrepancy arose from the short line levelled having been taken where the water was banked up by a large sand bank. By inserting the true slope in the formula a much larger discharge

would have been given; so that the experiments as far as they went showed that this formula could not be implicitly trusted without further verification. Thus both the general tests at that time accessible and the more special tests by Colonel Stoddard on the Irrawaddy itself made it clear that nothing short of direct measurement on the river must be had recourse to for the information upon which the investigation must be based. A similar conclusion appears also to have been come to by the Italian Engineers who have of late years undertaken similar investigations on the Tiber and on the Po; and also by the Dutch Engineers concerned in the distribution of the discharge of the Rhine through its various channels. In these and other cases of importance direct measurement has been resorted to.

The investigation pursued on the Mississippi river.

25. But though the precise formula obtained for the Mississippi could not be applied without further enquiry to the Irrawaddy; there was every reason to follow the methods of investigation carried out on the former river under the direction of Generals Humphreys and Abbot. The problems presented to them were in some respects similar though not identical with that of the Irrawaddy Delta Embankments. In their case, they had to consider the remedies to apply to meet the difficulties arising from constantly recurring disasters during floods to double embankments already existing throughout the greater part of the river. The works had originally been executed, as almost all embankment works in the world have been, without system or preconcerted design, and had been thrown up more or less regularly to meet the practical exigencies of each portion. They had rendered excellent service notwithstanding their deficiencies and had undergone great improvements in the hands of the Engineers in charge. But as they became more complete and shut in more of the inundation water from the country to the river channel, the necessity of a systematic revision was made apparent. The floods were more disastrous in their efforts and the damage to cultivation continually increased. The investigation was intended to discuss the character of the floods, the changes in the regime of the river, the defects of the existing embankments, and the remedies proposed to be carried out. As a collateral enquiry the existing state of hydraulic science had to be included in the subjects for investigation. The general method pursued was to take the discharge of the river by direct measurement at several different points; to compare these with those of its influents and effluents, whether breaches in the embankment, or branches, or spills over the banks; and from these to deduce the consequences, or the resulting state of the river, from a complete line of double embankments in perfect order acting efficiently during floods. The difference between such perfect embankments and the existing ones is the work still required to be carried out.

Details of the Mississippi method of current measurement.

26. The special method of taking the discharge was, after selecting a cross section of the river in the required position, and taking its profile as before described, to lay down a line parallel to it 200 feet higher up the river and join the two by a vertical line on the bank for a base line. At the end of this, observers were stationed with theodolites and watches. After some testing of various instruments the double float had been decided upon. This consists of a large float and a small one connected by a fine cord of any required length. The large float was a keg without top or bottom, ballasted to sink in the water, while the smaller one floats at the surface and holds the other by the cord at the desired depth below. Both floats tend to move with the velocity of the water immediately surrounding them; but the lower one being very much larger (in the Mississippi experiments 25 times) than the upper, drags it with it at its own pace. A small flag in the upper float permits the observers to record the time and position of its passage across the two lines 200 feet apart. The experimenters sought to determine the law of change in the velocities at the surface from side to side of the river; and also the law of change from the surface to the bottom. If these are known a limited number of observations permit calculation of

discharge to be readily made. Surface floats, or floats the lower of which were fixed 5 feet below the surface to avoid disturbance from wind and waves, &c., were thrown in above the upper line and the time of their passage over the 200 feet taken. This divided by the number of seconds gave the velocity per second. On plotting these velocities on a large scale as ordinates in their respective positions on a straight line representing the width of the river it was seen that the curve passing through these outer extremities resembled a parabola. Combination were made of a number of these and laws deduced from them. Sub-surface velocities were also taken. A boat was anchored some distance above the upper line; and a succession of floats thrown in at regular intervals of 6 feet or 10 feet. In some cases these were continued till the bottom was reached. Generally two or three were thrown in at the same depth, and the mean velocity of these was taken as the true velocity of the current at that point. A large number of observations for surface velocity were made in 1851 at three different sections at Carrollton and a few at other stations. In 1857 and 1858 other extensive surface measurements were made at five principal stations, and at several minor stations. The sub-surface velocities were only taken occasionally, and at the different stations. In all, these last numbered about 254 series, each series consisting of the observations of the set of floats thrown in from the anchored boat, while in the one position. It does not appear that more than three of these series were taken on any one day; and, generally, they are at intervals of several days or months. They were thus exceptional in character compared with the surface curves.

Details of the Irrawaddy method of current of measurement.

27. It is necessary to be somewhat precise in this description, as this method formed the point of departure for the Irrawaddy observations, which deviated from the others in some details of importance. Thus, while the necessity for the regular and continuous observations of the surface curves was admitted and carried out in 1872-73 without any change of the stations, it was further thought necessary to increase very much the number of sub-surface curves observed, as they are deemed still more important than the surface ones. The latter could be dispensed with if a sufficient number of the former were made. But it is found in practice much more difficult to take the sub-surface velocities than the others. Much time is lost in getting the boat into position on each occasion; and, as extreme importance is attached to the results for analytical purposes, it was necessary to take the most minute precautions to ensure the floats being thrown in, in the proper order of increasing depth, from the surface to the bottom. From thirty to sixty surface floats, the lower ones being one metre in depth, were thrown in while the boat sailed or rowed across the river. One half was thrown in and observed generally before the sub-surface floats were taken, the other half afterwards. In flood time the utmost number of series of sub-surface floats that could be observed in one day was ten; and this number was fixed as the usual one to be taken. The floats themselves were arranged and numbered always in lengths of one or more metres. The shortest was first thrown in, and the others followed at increasing depths of one metre till the bottom was reached. The depths of the river where the observations were made never exceeded 80 feet; so that no more than 25 floats were used for the largest series. It is believed that through increasing the number of these series the greatest accuracy of which measurement by floats is capable was attained. In all some 10,000 series have now been taken, which form a great store-house for deducing conclusions regarding the laws of flowing water.

Criticisms on the method of current measurement by double floats.

28. Some exceptions have been taken to the method of measuring the velocity of water by double floats, which require to be considered. Of these, part apply to the method itself, part to the mode in which it was applied on the Mississippi. These will only be now noticed so far as they serve to show what degree of reliance may be placed on the general results obtained. A complete comparison between this and other methods was in preparation by the writer, who had carried out tests of different instruments on the Irrawaddy, when

he learned that Captain Allan Cunningham, R. E., the able experimenter on the Ganges Canal, was also preparing one. At his request the writer made over some of the material, with various references gathered to him, and the result, from impartial hands, will doubtless soon be made known. The principal objections to the double float are:—first, that the cord connecting the upper and the lower floats interferes with the accuracy of the system as a record of the true velocity of the lower one. Thus in 100 feet in depth M. Bazin(1) pointed out that a cord 2/10ths inches diameter has $1\frac{1}{2}$ times the surface of the lower float; and thus the upper one, being drawn by the lower and the cord together, shows a mean of the whole of the velocities of the intervening layers of water. The objection is well founded when a large cord is used for great depths. But General Humphreys(2) points out in reply, that cords of 1/10th inch diameter were oftener used on the Mississippi than ones of 2/10ths, and that it was only rarely that such great depths were observed. On the Irrawaddy the cord was only 1/16th inch diameter; and the depths were generally smaller than those of the Mississippi. The floats, however, varied somewhat from those used on the latter river. They were universally 1 foot in height for the lower, 1 inch in thickness for the upper float; and 6 inches in diameter for both. The most economical float was found to be a cylinder of solid wood; with a hole 4″×4″ in its lower end to receive wet clay as ballast; which could easily be adjusted in quantity. This was always arranged before each experiment, so that the lower float could sink and draw the cord down, and hold the upper float at $\frac{3}{4}$″ immersion. The proportion between the cylindrical surfaces exposed was here as 18 to 1. On the Mississippi the rates varied, but were generally greater than this. In any case the objection is a valid one; and every effort should be made in similar cases to reduce the cord to a minimum.

The connection cord should be as small as possible.

29. It has further been objected that the double float should not be exclusively used, especially without testing it repeatedly with the various other instruments available. But, in practice, it was found both on the Mississippi and on the Irrawaddy that there are still more serious evils in the use of any other instruments known. The turbulent currents are described as hindering the use of current metres on the Mississippi. On the Irrawaddy there was such a mass of floating matter, like grass, trees and silt, that no such instruments can be trusted to act, out of immediate observation, for any time. They have been repeatedly tried and very rarely succeeded. They were used as tests of the float, and on the whole were not unfavourable. It would have been impossible, except at great expense, to have taken anything like the number of observations, actually obtained by the floats, with meters; and it is clear that any errors embodied in the system used must be of the same kind and degree in the simultaneous observations, so that all comparisons of the discharges of the same period will be valid. It is only in depths of over 20 feet that any errors in the use of the double float can arise on account of the cord. Captain Cunningham in India and General Ellis in America have proved their value for smaller depths.

The double float should always be tested at great depth with other instruments.

30. Another objection made by high authority is against the short distance between the parallel lines traversed by the floats. Herr Grebenau(3) shows from his own experiments, that an error of one second, or even of two or three arise in noting the time of traverse; and when the pace is rapid and the distance so short as 200 feet this introduces a serious error in the result. The writer tried several different distances between the lines before finally deciding to use the 200 feet width adopted for the Mississippi experiments. He found that, when every thing is in regular working order, errors of more than one second are not often likely to arise, especially at the greater velocities which almost never exceed 10 feet per second. The principal source of error is the great eye-weariness in following closely for a considerable time a small object with a

Objections to the distance of 200 feet between the measuring sections.

(1).—Baizin, M. Etu de comparitive des formules nonvellement proposeés 1871.
(2).—Humpherys, General. Report of the Chief of Engineers, 1875 vol. I p. 369.
(3).—Grebenau Herr. Die International Rheinstrom-messung bei Basel 1873.

telescope on the shining water surface; and the more the distance can be shortened within due limits the less this is. And the great number of floats observed in steady succession requires some time, while they also tend to equalize and lessen any tendency to error. On the whole, it is advisable not to give too great a course for the path of the floats to be observed, as side currents and whirls may move them from the general direction. The error in ordinary cases is rarely likely to exceed 5 per cent. It is found that, while all these points require careful attention and consideration in practice, the double float method of taking the velocities is the one which is most free from objection, and which unites in itself the greatest number of advantages, especially simplicity, economy and accuracy.

The principal results acquired from the Irrawadi experiments.

31. The results acquired by the experiments fall under two heads:—the one including the contributions made to hydraulic science, analytical and practical; the other the definite knowledge furnished regarding the discharge and the régime of the Irrawaddy river. The details of both must be left for the further Report. But a general notice of them is necessary here. It may be remembered that the cardinal principle of Du-Buat, which differentiates his school from that of Guglielmini and his predecessors is, that surface slope and not pressure is the cause of the flow of water in open streams. This principle, if rigorously true, entails as a necessary consequence that the maximum velocity of a current must always be at the surface of the stream, and the velocities must diminish from there to the bottom. Many experimenters found that the maximum velocity was not at the surface, but below it. The earlier ones explained this by errors of observation; but instances accumulated when this could not be admitted; and it became a recogized fact, declared abnormal and inexplicable, that very often the greatest velocity is found under the surface. Boileau(1) was one of the first to suggest that a new explanation, and a new physical basis for the science, had yet to be found. Messrs. Humphreys and Abbot's experiments proved that on the Mississippi and on smaller streams the maximum velocity was almost always below the surface, the results showing that it varied from this to the bottom. They, however, declare their belief (2) that "the truth of Du Buat's theorem that for all open channels the accelerating force arises solely from the slope of the water surface, seems undeniable." They supplement this with an experimental theory of their own; which has the great merit of first recognizing and generalizing as a fact the variability of the position of the maximum velocity. They deduce laws and formulæ from their experiments in accordance with this theory, which has only an empirical basis. Bazin also proves that in his small experimental channels of regular shape the same phenomenon habitually occurs; and most other observations since give the same result. Several ineffectual attempts have been made to explain it in accordance with Du Buat's principle, but on the whole there has been a breaking away from the old views, without arriving at new ones. M. Fournie's opinion has been given. Some writers, like the Author of the report on the Public Works of Holland for 1875, (3) seem indisposed to have any thing more to do with theories. They give very valuable experiments of their own and say:—"The results of these experiments might serve as tests in the search for a solution to the numerous theories raised by different experts. But the adoption of such theories exceeds the domain of positive fact, and is most dangerous in connection with stream measurements, leading to useless work and to erroneous conclusions. Continued efforts should be made to collect exact observations supported by clear evidence in order to throw more light on the essential relations of the flow of water in large rivers." Boileau, Dupuit and others have expressed similar desires for multiplied and accurate experiment, and this has been added to an unprecedented extent. But guiding principles are required to direct and arrange it, so as to make the required conclu-

Quotations showing confused state of the science of Hydraulics through want of a fundamental principle.

(1).—Boileau Captain La mesure des eaux courantes p. 261.
(2).—Humphreys and Abbott. Report on the Mississippi.
(3).—Verslag Aan den Koning over den Openbare Wirken in het yaar 1875.

sions evolve from a comparison of the results. Bazin saw this clearly when he said (1) :—"The question becomes more and more complicated and obscure, as new experiments more numerous and precise appear to throw a greater light upon it. What is to be concluded from' results so diverse and apparently contradictory, except that we do not yet possess sound notions on the internal movements of fluids and on the mutual action of their molecules?" It is then more than a mere accumulation of facts that is wanted. Without a principle for interpretation they encumber the science and throw it into hopeless confusion. Messrs Ganguillet and Kutter, who have done much to collect and arrange the most important results of experiment, after repudiating all connection with abstract principles for their elaborate formulæ, hope in concluding the last edition of their work (2) "that the knowledge gathered of late years may be explained by physical laws, and that a new theory, corresponding to the rich materials available from the results of investigations, may be developed."

Proposed new principle of the flow of water derived from the Irrawaddy Experiment.

32. It is with the view of meeting this recognized want that a new principle or theory of the flow of water in open channels has been brought forward. It is suggested by the experiments on the Irrawaddy, and by others. There are difficulties in the way of giving any account of this in a general and untechnical report; but a short statement of the principle, the evidence in favor of it, and its present position may not be out of place. It is a combination of the principles of Guglielmini and Du Buat; and asserts that both the pressure of the upper parts of a stream on the lower, and the surface slope are always efficacious in producing the flow. Guglielmini admitted that either might do so alternately, but both together never; and that usually only pressure operated. Du Buat, as often mentioned, excluded the action of pressure, and admitted that of surface slope alone. No other principles than these two can be admitted to explain the flow. A process of exhaustion in considering the whole of the conditions of the phenomena proves that gravity, which is the sole cause of the motion, acts only through these means and that in either one or the other or both of these principles the explanation must be found. The two have been tried separately and have failed. They have never before been tried together. There is therefore *prima facie* ground for their consideration. The suggestion to try them arose from a discussion of the results of the Irrawaddy experiments. Previous experiments had shown that, in entire contradiction to Du Buat's principle, the maximum velocity of a stream was below the surface. The Irrawaddy experiments proved that, as the depth of a stream increased, the maximum velocity tended to approach the bottom. Here the increased pressure from the greater depth served to explain the peculiarity. On comparison it was found that the same law subsisted in the Mississippi experiments, but had not before been observed. Selections and combinations of the Irrawaddy experiments were made by M. Bazin and the author, and the tables published in the paper on the theory of the flow of water. It is intended to reproduce these, with others, in the technical report. These clearly prove that the different series of velocities on vertical lines from the surface to the bottom, generally called vertical curves, became more upright with the increase of pressure, whether taken at the same stand of the river surface at increasing depths on the same section; or at the same point of the section with increase of depth from low to high water. Professor Bornemann, the learned editor of the *Civil Engineer*, and author of a work on Hydrometry, in a careful criticism in that paper, since translated for Van Nostrand's magazine (July 1877), considers that this position has been fully established by the writer from the data. But he thinks it possible the phenomenon may be due to local peculiarities of the river, a view shared by Captain Cunningham, while M. Bazin suggests that it may be due to the use of double floats. The writer is now prepared to show from the experiments of M. Bazin, of Captain Cunningham and others, as well as from those of the Mississippi and the Irrawaddy, that the pheno-

(1).—Baizin M. Researches Hydrauliques 1865.

(2).—Ganguillet and Kutter Messrs, Die Bemegung des Wassers in Canalin and Kussen, 1877.

menon is a general one; and can only be explained by a resort to the pressure theory.

Further and more crucial experiments necessary.

33. But something is still required to make out a satisfactory case. Eminent hydraulicians have shown every desire to consider fairly the data and the arguments, and some have rendered efficient aid. It is only due to them that all should be done to render the evidence as complete as possible; and the writer is compelled to acknowledge that this is far from being the case. There is no desire, and no hope to establish the principle at once as a complete theory. There is no royal road to success for a new principle of this kind in science. The utmost that can be expected is to establish its claims to be considered as a working hypothesis; and, even here, it should be challenged at every step, and submit to the most rigorous tests. It can only be admitted to the opportunity of undergoing such tests in varied conditions by the consensus of opinion of the most eminent students of the science; and it is after satisfying these, and by the labors of conscientious workers in all parts of the field of research pertaining to it, that it can be ultimately recognized as true, and take its place as an established theory. The experiments already available do little more than suggest its credibility. There is one decisive experiment, which, in the writers opinion, and in that of different eminent authorities, would either disprove it altogether, or advance its claim to notice by all experimenters. Both Guglielmini and Du Buat point out that the order of the velocities from the surface downwards is disturbed by the retarding effects of the bottom of the channel. If this effect could be eliminated, the true theoretical order of the velocities could be ascertained. The vertical sides of a channel can have no disturbing effect on the order of the velocities in a vertical curve. Therefore if a very deep and narrow channel were constructed, with an extremely smooth bottom and rough sides, experiments on the flow would prove if pressure can be admitted as an efficient cause. For the last three years the author has tried to induce different authorities to undertake this experiment; but the trouble and expense are obstacles. Captain Cunningham, with whom he has corresponded on the subject, and who is eminently qualified both to judge on the matter and to make the experiment, entirely concurs in the desirablity of making it (1). An estimate of the cost has been prepared, and plans drawn out; and if the sanction of Government can be given to this most desirable work, it might be conducted under his auspices at Roorkee.

Criticism on the new principle.

34. As it is, the writer has endeavoured to show that it is possible from this new principle both to explain the flow of water, and to deduce according to known laws of mechanics, a general formula from it such as General Morin, in the extract before given, considered to be difficult or impossible to achieve. This formula was given in the 1873 paper of the writer. Different tests were given for its generality; and its mode of derivation from the theory explained. Herr Bornemann in his criticism on the paper acknowledges the generally confused state of the science and the necessity of a new departure. He agrees that all the formulæ hitherto proposed are based on only empirical foundations; but points out that the writer has not made the connection between his formula and the new principle sufficiently clear. It, however, fulfils the conditions practically demanded of it as a general formula. It, in Herr Bornemann's opinion, satisfactorily corresponds in its results with the experiments of M. Bazin on the small channels of varying slope, and different degrees of roughness of lining; and with those of the larger river, the Irrawaddy. "It cannot be denied that the formula given answers very well." He concludes that (2) "although the new theory requires further proof, the research appears always to

(1).—Cunningham Captain Allan. Roorkee Professional Papers 1878.

(2).—Bornemann K. R. Neuer Literatur uber die Bewegung des Wassers, p. 35. "Die Gordonn's schen Versuche flössen indessen ein weit grosseres Vertrauen ein."..."Wenn also die neuere Theorie auch wohl weiterer Prufung bedarf, so erscheint dieser Versuch doch immerhin sehr beachtenswerth und ist das vorliegende Werk unbedingt mit zu den interessantesten Erscheinungen der Neuzeit auf diesem Gebiete der Literatur zu rechnen.

be very valuable, and the work discussed must be reckoned one of the most interesting contributions of the present time to this branch of literature." The delay in bringing forward the discussion of the special problem of double embankments for the Irrawaddy, will be of the highest benefit to it, if it permits the few experiments required before a satisfactory discussion can be completed, and a matured and well considered conclusion given, to be sanctioned and carried out.

Method of calculating the discharge from the current measurements.

35. The process of working out the discharges of the river from the different series of surface and sub-surface velocities will be given with complete specimens and details in the further report. At Saiktha the width of the river at high water was 4,980 feet from bank to bank. A large sloping sand bank diminished the width of the channel as the river fell, till, in low water, it was under 3,000 feet at the water surface. On examining the daily records of the surface velocities, it was found possible to arrange them in groups of nearly equal velocity, in sub-divisions of the total section, which remained each the same throughout all the stages from low to high water. Thus at high water ten sub-sections called A. B. C. and D. to K. were divided at points measuring 220, 500, 1,400, 2,400, 3,000, 3,700, 4,200, 4,600, 4,900, 4,980 feet from the right bank, in 1872-73 at Saiktha. In 1875, at very high flood, it was found that water was spilling over the left bank and passing down a broad shallow channel between it and the high ground. A new sub-division with two groups was practised. The old ones were kept to 2,400 feet, and then divisions made at 3,600, 4,000, 5,000, 6,200, 7,000 and 7,800. The quantity of water in this channel was not comparatively great even at highest flood. The sub-sections on the left bank were dropped out of the calculations as the water cease to flow in them. The areas were calculated out for each sub-section for every day on which observations were taken. This was the first step in the process. The second was to obtain the average of all the surface velocities falling into each sub-section on each day. These averages were to be multiplied by the corresponding areas of sub-sections for the day. This result would not have given the accurate discharge. The ratio was found between the mean of the velocities on a vertical series, or curve, and the surface curve. It was assumed that this same ratio subsisted between the whole of the surface velocities in the same sub-section and those of the layers of water vertically beneath them. Although the vertical series were comparitively numerous, 10 for each day, it happened that sometimes 2 or 3 fell in one sub-section while others got none. The ratios obtained from these verticals were found to vary from one place to another on the same cross section, and also on the same subsection taken for a considerable time with varying heights of the river, according to the law before mentioned. But it was found that they were practically permanent for a few days at a time during the same state of rise or fall of the water surface. The gauge record was accordingly examined, and the readings divided into groups containing days of similar condition of the river for continuous intervals. A mean was then taken of all the rates of the vertical velocities to the surface velocities falling in the sub-section for these days. This gave a second multiplier, with which the previous one of mean surface velocity and the corresponding area was multiplied. The product was the discharge for the sub-section. The sum of these products for each day gave the total discharge on that day. The whole of the elements were subjected to a careful scrutiny, and elaborate precautions taken against error at each stage of the process; while the final results for contiguous days checked each other.

Interpolation of lacunes in observations.

36. Slight discrepancies and irregularties were sometimes found; though, on the whole, there was a close agreement in the results. Several days had been omitted in the course of the observations; Sundays and holidays, with occasions of storm, &c., which hindered them being taken. It was necessary to interpolate these lacunes in order to obtain a complete summation o

the discharge; and it was desired to extend the calculation over the whole time during which gauge records have been kept of the height of the river. The former has been done as far as possible by simple interpolation of quantities proportionate to the rise of the gauge on the days not observed. For the latter purpose it was necessary to obtained a scale of the approximate discharge for each interval of the gauge height. The whole of the observations from low to high water was plotted on a large scale, one set of co-ordinates being the gauge heights, the other the corresponding discharges. An even curve was made to pass through these, so as, as nearly as possible, to make the excesses balance the deficiencies. It was found that two curves were required, one for the rising state of the river, the other for the falling. It was then sought to obtain by calculation a curve corresponding to the one laid down on the plan. The method of least squares was considered, but found altogther impracticable. The number of observations was immense, and it would have involved excessive labour to express them in the complicated formula and process; while it is not clear how a continuous set of inosculating regular curves, which it was finally found practicable to construct for the discharge scale, could be deduced from this or other such processes. It was finally resolved to resort to the calculus of finite differences; and by a long series of trials and adjustments two or three inosculating parabolas of the second and higher dimensions were found to give a close agreement to the average results required. The observations and the scale curves are given for Thabingyo on the Nawoon, in Plate XXIII. The whole of the details for this are required in the fourth part of this report for the discussion of the floods in that river. But to permit a present judgement of the adequacy of this process as applied at Saiktha, the measured results and those calculated from the scale are given for the whole of the measuring periods of 1872-73 and 1875 in Appendices III and IV with the figures of the scales for those years. In a few cases the differences exceed 10 per cent. as for the period from 22nd to 26th April 1873, probably due to a strong north wind on those days.

Constructions of scales of discharges.

37. In resuming the measurements in 1875 it was found that a marked change had occurred in the height of the low water on the gauge at Saiktha. A bar had formed on the river about 5 miles below the measuring station, which raised the low water surface from 2 to 3 feet higher than formerly; and there was a slight change in the cross section itself and in its capacity in the two years from 1873 to 1875, New scales were accordingly constructed from the measurements taken; and the flood discharge of the year 1877 has been worked out from these for the purposes of the present report. As the special report has a practical result of the highest importance in view, only the most trustworthy results, as derived from the actual measurements made, can be used in it. For present purposes of general information a less degree of accuracy is requisite. The gauge at Saiktha had only been recorded during the time of measurement from July 1872 to September 1873. During this period it was found to correspond pretty closely in range from high to low water, and in each oscillation, with the Myanoung gauge; and on taking the averages of the readings for all that time it read with some uniformity about $\frac{1}{2}$ foot lower. By altering the scale of discharge, therefore, by $\frac{1}{2}$ foot it served for calculation with the Myanoung gauge record for the whole time this had been recorded; and the latter section has the advantage of not having been altered much, as the continued correspondence of its gauge with all the other gauges proves, for several years. This was in every way fortunate; as the changes from 1873 to 1875 at Saiktha would have rendered the use of either scale from the records at that place impossible. The discharges have accordingly been calculated out from the Myanoung records for the whole time 1869 and 1877 with the exception of the periods of actual measurement. It is probable that the results rarely vary more than ten per cent. from the truth, which is sufficiently accurate for any general purpose. The whole of the discharges, day by day; from 1869 to 1877

Changes at Saiktha Cross Section from 1873 to 1875.

Adaptation of Saiktha scale to Myanoung Gauge.

are given in Appendix ; and are depicted graphically in Plate V. An abstract of these for each month and year is given on the opposite leaf with some of the most noticable points, as the greatest and least discharge, the percentage for each month, and the averages for each month and year.

Recapitulation.

38. Repeated reference has been made in the course of this report to the results of discharge obtained, whether as totals, monthly and yearly averages, or in the more abnormal deviations from the average towards great flood or drought. So far as the data accessible permitted, the various gathering grounds and the meteorological conditions furnishing these discharges have been considered. Recapitulated briefly, it was considered that while the greater portion, or at least two thirds of the discharge comes from the region to the north of Mandalay and Bhamo, principally from Thibet, the high floods in the delta are due to a combination of floods in the upper part of the river with heavy rainfall and discharge in the lower. The most extreme floods arise from sudden and extreme falls in the hill regions with torrent streams just above the delta, supervening on an already filled channel. The great body of the water reaches the delta in the six months June to November. Seventy four per cent, or three fourths of it, comes down in the four months July to October. The four months January to April furnish between 1 and 2 per cent ; the two May and December less than 3 per cent each. What proportion these amounts bear to the rainfall it is impossible to say. It is unquestionable that by far the greater portion of the rain falling in the northern countries in the hot months never reaches the delta ; but is absorbed and evaporated, the portion draining off forming but a small part of the total. In August, after very heavy rain in June and July, the ground on the hill slopes may be fully saturated, and all the rainfall be rapidly precipitated into the affluents of the river to be brought down to the delta. There will thus be every degree of proportion between rainfall and the discharge according to the seasons ; but it is probable that on the whole year and from year to year, only from $\frac{1}{3}$ to $\frac{1}{2}$ of the rain falling on the various drainage grounds, is discharged to the sea through the river channel. The discharge averages 424,763 million metre-tons. There are 4,168 million metre-tons in a cubic mile, so that somewhat over 100 cubic miles of water reaches the sea yearly through the delta as a result of from 200 to 300 cubic miles of rain thrown down in the valley. The diagram of discharges shows that it is but rarely that the discharge at Saiktha reaches 1 cubic mile per day. It did so once in 1871. In 1875 it continued for a week bringing down over that amount ; and in 1877 it exceeded it on two occasions, altogether for 14 days, reaching nearly $1\frac{1}{4}$ cubic mile on one day.

Table 14.

Discharge of the Irrawaddy River at Myanoung in metre-tons.

Years	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total discharge for each year.
1869	...	...	...	...	...	34,765,499,860	76,105,405,900	83,129,560,800	71,926,954,600	67,585,097,800	14,548,196,480		
1870	7,784,560,960	5,352,928,040	4,723,168,500	5,703,339,980	7,489,372,280	23,889,172,240	83,128,778,160	93,661,181,220	87,377,200,500	53,624,269,500	19,922,747,040	12,839,276,440	405,495,994,900
1871	7,931,747,860	5,248,853,960	6,768,772,420	9,339,342,640	11,555,532,840	44,536,287,840	88,977,030,860	102,173,847,920	94,451,981,760	58,366,151,900	36,701,425,700	15,588,073,600	481,639,049,300
1872	9,852,990,780	6,798,773,620	6,212,467,160	6,517,161,600	14,014,777,860	21,036,761,600	85,529,495,380	94,557,343,680	77,758,373,400	81,917,359,980	32,915,434,980	14,445,287,360	451,556,227,400
1873	9,640,860,600	6,663,855,280	6,466,004,340	6,594,821,880	8,663,618,960	37,160,697,280	68,222,287,000	85,100,009,680	63,013,555,700	52,263,959,240	26,986,522,480	10,812,722,460	381,588,894,900
1874	6,706,840,840	7,812,304,380	6,491,819,560	10,672,768,480	18,234,967,180	23,806,945,980	73,196,606,040	66,859,213,000	75,221,939,260	64,483,583,320	26,662,689,780	11,787,789,580	388,937,467,400
1875	7,819,046,720	5,538,467,980	6,087,990,460	10,983,351,300	21,647,452,920	45,354,289,660	94,027,283,760	109,506,569,980	84,249,129,570	49,939,140,050	19,734,342,580	10,575,437,040	465,442,502,020
1876	6,662,423,840	4,665,610,940	6,171,721,380	9,003,367,300	10,555,613,960	27,887,805,580	88,970,275,980	98,754,458,200	53,141,862,860	46,041,450,880	19,535,670,080	10,277,036,180	381,667,297,180
1877	5,978,016,080	4,463,610,440	4,166,609,100	8,055,460,540	7,140,188,860	31,489,827,520	66,882,182,700	122,604,179,620	86,515,369,560	84,336,110,520	30,300,864,080	14,187,872,920	466,120,288,980
Total ...	54,591,926,720	43,544,404,640	47,088,552,920	66,869,613,720	99,301,524,860	289,927,287,560	725,030,345,780	856,346,364,100	69,365,367,210	558,557,123,230	227,307,890,200	100,513,495,580	3,422,447,722,000
Monthly Average...	7,784,560,960	5,443,050,580	5,886,069,115	8,358,701,715	12,412,690,607	32,214,143,062	80,558,927,309	95,149,596,011	77,072,929,690	62,061,902,581	25,256,432,244	12,564,186,947	424,763,190,821
Percentage	1·84	1·28	1·39	1·97	2·93	7·59	18·99	22·41	18·15	14·53	5·93	2·99	

The greatest discharge took place on the 20th August 1877, when 4,990,985,480, metre-tons in one day ; or at the rate of 2,040,123 c-ft. per second passed down the river at Myanoung. In the flood of 1875 the greatest was 4,608,024,970 tons on 17th August ; and in 1871 the discharge reached 4,091,620,500 tons on 7th August. The lowest measured discharge was 193,183,000 tons on 3rd March 1873 or 78,966 c-ft. per second ; while the smallest ascertained from computation occurred on 5th March 1877, when it was 112,892,940 tons in one day, or 46,146, cubic feet per second.

SECTION II.

The silt carried by the Irrawaddy discharge.

The formative action of the floods.

39. The mere mass of the water brought down by the Irrawaddy is imposing; but it acquires its greatest significance when its plastic and formative energies are considered. It would be taking very narrow views of the floods and their action if they are considered only as destructive agencies whose principal teleological reason for existence is to discompose embankment arrangements and hinder the spread of agriculture. Under their cutting and scooping out action the mountains and higher valleys take definiteness of outline, while the lower valleys and plains, and especially the delta, owe their existence and principal features to them. It is by their periodic repetition through countless years, bringing down the washings from Thibet and from the east and west Yomas and intermediate valleys, and depositing and arranging them according to definite laws that this magnificent and rich country with its dense virgin forests and submerged tracts, its scattered cultivation and villages and towns, augurs of the vast possibilities in rapid course of realization, has been formed and fitted to its present position and future prospects. It is desirable to ascertain to what extent these processes are now in operation; as it is only by studying and conforming to the laws by which nature carries on its works with silent but irresistible power that our feebler efforts have any chance of arriving at success.

Silt observations on the Irrawaddy.

40. The quantity of water passing through the delta being known, it was desired to ascertain the amount of silt it carried. Observations were accordingly made on the main channel at Henzada for a whole year from March 1877 to March 1878. A wooden barrel about one foot long by six inches in diameter was provided with large valves on the top and bottom, both opening upwards. The valve lids are of leather and weighted with lead so as to lie close on the wood. One end of the leather is screwed down, the other rises freely. The barrel itself is loaded with leaden rings so as to make it sink rapidly in the water. The valves both open with the rush of water through the barrel when it sinks, and the contents of the barrel always correspond with the water at the lowest depth reached. On hauling up the barrel the pressure of the water keeps the valves tight, and samples of water can thus be taken from any required depth. A boat was sent out to mid stream every morning about 8 o'clock, and samples of water taken from just below the surface, from about mid depth, and from the lower part of the river, not too near the bottom. The samples were taken fresh from the barrel, which was shaken up, and put in clean quart bottles, sealed and marked with date and position. After a number of samples had been gathered, 100 grammes were taken from each of the bottles for one week after careful admixture by shaking. The surface samples were combined together; as were those of the mid depth and lower parts. Each combination of seven samples was filtered separately from the others. A double thickness of filter paper was carefully weighed against a sample paper of the same kind kept exclusively for that purpose. It was at first tried to let the 700 grammes of each filtering settle; and, draining off the clear water, filter only the residue. But it was found that equally good results were obtained with proper precaution, in filtering the whole mass gently through the papers. When the whole of each sample had been passed through the paper this was carefully folded, marked in pencil, and dried. Before weighing it was again dried in identical condition with the sample paper it had before been weighed with. The two were again weighed against each

Method used in weighing the silt.

other in an excellent Fortin's balance, capable of showing a difference of $\frac{1}{10000}$ of a grain. The difference in grammes was the weight of the silt in each sample. In most of this process the Mississippi operations have been followed. Mr. E. M. Sage, Assistant Engineer, carried out the weighing personally, and every possible precaution has been taken against error. The accompanying Tables have been worked out by him from the results.

Description of results given in Table 15.

41. The first column gives the dates taken week by week; the second shows the stage of the river by the Myanoung guage at the time the samples were taken. In the third are given separately in sub-columns I, II and III, the quantities of silt contained in each 100 grammes of water at the surface, at mid depth and near the bottom of the stream. An examination of these shows a fair accordance in the proportion of silt of the several samples on the same weeks, and during the same states of the river. The upper and mid depth quantities of silt are generally about the same, with a tendency to increase on the lower of the two. There is a very great increase in the bottom sample over the others; and this occurs throughout the year at all stages. It is most marked at low water, when there is about six times as much silt on the average in the lower layers of the stream as in the upper. In the higher stages it varies from two to three times the quantity. This is possibly due in some cases to the samples having been taken too low down, near the bottom, where the whole soft bed of the river is in commotion; but in cases where the water was carefully taken at a distance from the bottom the same result was found. It has also been found that the current-meter gathers silt sooner in the lower layers when at some distance from the bottom than in the upper; and it would appear due to the action of the water in disturbing the alluvial deposit of which the bed is composed rather than to the general silt bearing powers of the stream. On comparing the weights of silt with the gauge readings, it is seen that there is a decided variation in the quantities carried in the different states of the river. In grouping the results a somewhat arbitrary division must be made. The river rarely stands for any time at the intermediate stages between low-water and high-water, or between 6 and 26 feet on the Myanoung gauge.

Table 15.

Silt Observations and corresponding Gauge Readings for 1877-78.

1			2			3			4	5	6	7
Date.			Myanoung Guage Readings.			Silt Observations weight per 100 grammes.			Mean of (I) (II) (III.)	Aggregate Mean of (I) (II) & (III.)	Mean of (I) & (II.)	Aggregate Mean of (I) & (II.)
			Maximum.	Minimum.	Mean.	Surface (I.)	Mid depth (II.)	Bottom (III.)				
1877.												
March	8th—14th		—·64	0·50	0·570	0·008	0·0088	0·043	0·0199		0·0084	
,,	15th—21st		—·58	0·39	0·485	0·009	0·017	0·031	0·0190		0·013	
,,	22th—28th		—·50	1·04	0·382	0·004	0·0046	0·161	0·0558		0·0043	
,, Apl.	29th— 4th		3·85	1·06	1·90	0·010	0·005	0·022	0·0123		0·0075	
April	5th—11th		4·10	3·94	4·031	0·003	0·004	0·007	0·0046		0·0035	
,,	12th—18th		4·00	2·58	3·472	0·003	0·001	0·007	0·0036	0·0220	0·002	0·00949
,,	19th—25th		2·29	1·83	2·008	0·004	0·002	0·005	0·0036		0·003	
,, May	26th— 2nd	Low Water.	2·92	1·77	2·377	0·006	0·007	0·015	0·0093		0·006	
May	3rd— 9th		1·77	1·31	1·455	0·006	0·067	0·014	0·0090		0·006	
,,	10th—16th		1·25	0·69	0·89	0·001	0·0078	0·007	0·0052		0·004	
,,	17th—23rd		1·33	0·79	1·168	0·024	0·016	0·043	0·0276		0·020	
	Average ...		...	...	...	0·005	0·006	0·033	...		...	
,,	24th—30th		7·38	1·65	3·495	0·0325	0·025	0·050	0·0358		0·287	
,, June	31st— 6th		14·67	9·23	12·058	0·0425	0·0355	0·071	0·0496		0·039	
June	7th—13th		12·46	8·27	9·51	0·114	0·133	0·165	0·1373		0·123	
,,	14th—20th		17·96	8·40	11·82	0·056	0·057	0·057	0·0566	0·0768	0·056	0·0595
,,	21st—27th	Rise.	24·96	19·38	22·425	0·0727	0·0794	0·100	0·0840		0·0760	
,, July	28th— 4th		25·69	24·17	24·828	0·058	0·072	0·093	0·0743		0·065	
	Average ...		...	...	...	0·051	0·054	0·095	...		...	
July	5th—11th		29·15	27·35	28·24	0·078	0·0797	0·143	0·1002		0·0788	
,,	12th—18th		27·29	26·63	27·03	0·0295	0·0365	0·122	0·0626		0·033	
,,	19th—25th	Mean Flood.	27·69	24·98	26·14	0·0225	0·0357	0·179	0·0790	0·0693	0·0291	0·0404
,, Augst.	26th— 1st		33·25	28·08	30·62	0·036	0·0438	0·1218	0·0672		0·039	
	Average ...		...	...	...	0·035	0·038	0·111	...		...	
August	2nd— 8th		38·42	33·83	35·67	0·0338	0·049	0·187	0·0899		0·0414	
,,	9th—15th		40·35	39·25	40·02	0·0589	0·085	0·308	0·1506		0·0719	
,,	16th—22nd		40·96	37·92	39·61	0·045	0·070	0·158	0·0910	0·1040	0·0575	0·0548
,,	23rd—29th		38·25	36·46	37·07	0·0405	0·045	0·133	0·0728		0·0427	
,, Sept.	30th— 5th	High Flood.	38·79	35·94	37·937	0·0365	0·088	0·245	0·1231		0·0622	
Sept.	6th—12th		34·35	24·44	28·44	0·0415	0·065	0·185	0·0971		0·0532	
	Average ...		...			0·043	0·067	0·203	...		...	
,,	13th—19th		32·46	26·21	29·75	0·099	0·125	0·1087	0·1042		0·002	
,,	20th—26th		35·77	33·00	34·55	0·029	0·0337	0·065	0·0425		0·031	
,, Octr.	27th— 3rd	Mean Flood.	36·00	35·50	35·797	0·028	0·023	0·152	0·0676	0·0693	0·025	0·0404
October	4th—10th		36·13	35·44	35·73	0·0335	0·028	0·144	0·0618		0·0307	
	Average ...		...	...	...	0·035	0·038	0·011	...		...	
,,	11th—17th		36·67	35·00	36·09	0·0287	0·011	0·105	0·0482		0·019	
,,	18th—24th		34·02	25·00	29·70	0·021	0·037	0·056	0·0380		0·029	
,,	25th—31st		27·88	19·56	23·45	0·0525	0·070	0·137	0·0865		0·0612	
Novr.	1st— 7th		20·06	19·08	19·50	0·0507	0·049	0·0878	0·0625		0·0498	
,,	8th—14th		19·44	18·27	18·638	0·065	0·056	0·130	0·0836		0·0605	
,,	15th—21st		18·00	12·56	15·088	0·035	0·029	0·0535	0·0391	0·0513	0·032	0·0323
,,	22nd—28th		12·04	9·92	10·88	0·020	0·198	0·0665	0·0354		0·0199	
,, Decr.	29th— 5th		9·60	8·21	8·887	0·016	0·0128	0·0977	0·0421		0·0144	
Decr.	6th—12th		9·04	8·08	8·578	0·0228	0·0268	0·0677	0·0387		0·0248	
,,	13th—19th		8·02	6·56	7·167	0·0276	0·021	0·083	0·0438		0·0243	
,,	20th—26th	Fall.	6·27	5·50	5·908	0·0217	0·020	0·0977	0·0464		0·0208	
	Average ...		...	...	...	0·033	0·033	0·089	...		...	
1878.												
Decr. Jany.	27th— 2nd		5·31	4·60	4·80	0·0074	0·011	0·1025	0·0403		0·009	
Jany.	3rd— 9th		4·50	3·98	4·24	0·009	0·0055	0·0692	0·0279		0·007	
,,	10th—16th		5·00	4·04	4·57	0·002	0·006	0·052	0·0200		0·004	
,,	17th—23rd		4·00	3·08	3·478	0·002	0·0028	0·0308	0·0026		0·0024	
,,	24th—30th		2·98	2·69	2·82	0·002	0·007	0·0528	0·0203	0·0220	0·004	
,, Feby.	31st— 6th		2·60	1·98	2·28	0·0141	0·0155	0·0422	0·0239		0·0148	0·00949
Feby.	7th—13th		1·90	1·63	1·78	0·017	0·016	0·044	0·0256		0·016	
,,	14th—20th	Low Water.	1·54	1·08	1·26	0·0278	0·031	0·082	0·0469		0·0294	
,,	21st —27th		3·38	1·25	2·58	0·0238	0·034	0·130	0·0626		0·0289	
,, Mar.	28th— 6th		4·88	2·38	3·147	0·006	0·0065	0·087	0·0331		0·0062	
	Average ...		...	...	...	0·005	0·006	0·033	...		...	

It is here in a continual oscillation of rise and fall, and these states may continue from lowest water to highest flood. Low water may be taken at any height below 6 feet marked on the above gauge. Mean flood is the stage between 26 and 36 feet without rapid rise or fall; and high flood anything above 36 feet, though it must include the whole of such a flood wave as that of August 1877. Taking the mean of all the observations from the surface, mid-depth and bottom parts of the stream, the results vary from 2·2 parts by weight of silt per 10,000 of water, with a mean velocity of the river of $1\frac{1}{4}$ to $2\frac{1}{4}$ feet per second, to an average of 10·4 parts at high flood with mean velocities of the river from $5\frac{1}{2}$ to $7\frac{1}{2}$ feet per second; the maximum velocity not exceeding 11 feet per second at the measuring station, though elsewhere it has been found greater. There is a decided increase in the state of rise, when the silt is 7·7 parts per 10,000, over the 6·9 of mean flood, and the 5·1 of the falling state of the river. It is worthy of note that, on combining the high flood with the low water ratio, rise with fall, means of 6·3, and 6·4 result, which agree nearly with the mean flood ratio of 6·9 parts of silt to 10,000 of water. The least quantity was recorded in May, at the surface, when the gauge was at a mean of 0·89, and the river velocity averaged $1\frac{1}{4}$ feet per second. The silt was then 0·1 part in 10,000 at the surface. A similar result was obtained in April, but this was marked questionable. The highest proportion occurred about the time of the great flood of August 1877, when 30·8 parts per 10,000 were taken in the bottom samples. The ratios in the upper parts of the stream were exceptionally high at the same time; a series of facts worth noting in association with the recorded velocities, which show an immense increase of speed at the bottom, over that of the upper layers in high flood.

Definition of the stages and states of the river.

42. The results obtained are directly comparable with those derived from the experiments made at Carrollton in the Delta of Mississippi in 1851-52 by Professor Forshey. These were continued for a whole year in a more elaborate manner than the Irrawaddy ones, and formed the model on which the latter were based. The details are given in the Mississippi Report p. p. 136—143. Samples were taken in the method described for the Irrawaddy, but at three different positions in the same cross section; one 300 feet from the east bank; one in mid stream; and the third 4,000 feet from the west bank. At the first two positions they were taken at the surface, at mid depth and at bottom; at the last one at surface and bottom only; in every case for six days of every week. The six samples of 100 grammes for each place were combined, carefully filtered with unusual precautions, and weighed. The totals of silt for the year are, in 52 samples of 600 grammes each; in grammes

Comparison of silt observations on the Irrawaddy and on the Mississippi.

First position depth 100 feet.			Second position depth 100 feet.			Third position depth 40 feet.	
Surface.	Mid-depth.	Bottom.	Surface.	Mid-depth.	Bottom.	Surface.	Bottom.
15·302	17·552	17·880	15·150	18·977	19·538	13·845	20·070
–	The	corresponding	ratio by	weight in	10,000 parts.		
4·9	5·64	5·73	4·86	6·08	6·26	4·43	6·43

The averages for all these are 4·7 for the surface, 5·85 for the mid-depth and 6·14 for the bottom of the river. Similar averages for the Irrawaddy obtained by taking the means of the figures for the five different states of the river are 3·3, 4·0 and 10·6 respectively. There is apparently a great diversity in the results, which is in a measure explainable. In taking the mean of the five different states an undue preponderance is given to the low and falling stages of the river; which though they occupy eight months out of the twelve only discharge from 25 to 30 per cent. of the water. This gives a rather low average for the

year in the main body of the water, compared with that of the Mississippi whose mean flood stage, during which the highest ratio of silt to water is obtained, lasts a much longer time. The mean flood stage of the Irrawaddy gives the figures 5·1, 5·4 and 9·5 as the parts of silt in 10,000 of water. These are more nearly equal with the Carrollton ratios of the great American river; but the lower parts of the streams show great diversity. As will shortly be explained these ratios of silt to water are of very great importance in practical questions, and this comparatively small increase in the silt at the bottom over that at the surface at Carrollton is very noteworthy. Carrollton is low down in the delta, about 100 miles above the head of the passes; the surface of the river has a very small slope there, ranging from ·008 feet per mile at low water to 0·146 at high. The bottom of the river bed thus lies low beneath the height of the bars in the passes which must hold back the lower parts of the stream considerably, while the continually diminishing slope of the surface implies a loss of energy in the mass of water discharged. The river is thus less apt to act on its bed and banks in excavating and moving them. There is thus, with the small bottom velocity of the water, and diminishing energy little fresh stirring up of alluvium on the bottom. The Irrawaddy at Henzada, which is high up in the delta has a considerable slope of from 1¼ inches per mile at low water to 4 or 5 at high (0·01 to 0·04 feet), and there is little sign of diminishing energy in moving the bed and banks. The channel is entirely composed of soft alluvium, mostly moveable with great facility by the lightest currents, which stir up the lighter particles, and carry them near the bottom without their rising through the whole section of the stream. The Mississippi report gives an account of further extensive observations upon that river, as well as upon European rivers. The most noteworthy of these mentioned is that of M. Surell in the delta of the Rhone, where he found the proportion of surface to bottom silt to be as 100 to 188; but the amount held varies in different parts of the river. The proportion in low water on the upper river was 1·4 parts of silt per 10,000 of water at low stage, with a general maximum of 41·7 in floods, the very highest rates known being 222 parts per 10,000 at mean flood, with a velocity of 8 feet per second.

Silt observation on the Rhone.

43. The Ganges, where it leaves the Sewalik Hills at Hurdwar, was measured for silt by Mr. Medlicott, geologist, who found it carrying a minimum of 0·09 parts of silt to 10,000 of water on 1st May 1857. Its maximum ratio was 23·1 parts on 2nd. August 1856, but the ratio had fallen to 13·3 parts 18 miles lower down in the plains at Asufgurh on the same day. Colonel Medley took the ratio on the Ganges Canal at Roorkee about the same period, and found on 31st July 1857, no less than 228·8 parts of silt in one sample, and 148·5 in another per 10,000 with a 9 feet flood. Mr. Login noticed that, however clear the water entered at the head of the canal, it rapidly took up large quantities of silt from the canal channel. In the cold weather he could see clearly a rupee in ten feet depth at the head of the canal; at the sixth mile it could not be seen at 5 feet, at the twentieth mile at 3 feet, and at the fortieth the water was full of silt. Colonel Tremenheere measured the ratio of silt carried by the Indus at Sukkur, and that of some of the canals derived from it. The river is there comparatively shallow, the flood observations not being made in depths of over 12 feet. The velocities ranged from 2·6 to 9·5 feet per second. Samples were taken from all depths from surface to bottom with very slight differences in the results, as if the admixture of the silt with the water was general. The mean of the high water ratios was 42·2 parts of silt per 10,000 of water. The maximum occurred with a velocity of 3·1 feet when 64·9 parts were obtained. At low water the mean of the observations gave 19·4 parts per 10,000, the minimum being 10 parts, thus showing an unusally high ratio. In the canals of derivation silt was rapidly deposited, the flood quantities measured about the same time as those on the Indus giving ratios of 22·8, of 24·3, of 5·6 and 19·1, instead of the 42·2 of the Indus water, on four different canals at some distance from their heads.

Importance of knowledge of silt ratios.

44. The ratios of the silt bearing powers of a stream are of much more practical importance in discussing its hydraulic conditions than either the mass of water or of solid matter brought down by it; as they indicate the peculiar stage in its operative process, whether it be excavating or depositing, that is, in unstable régime, or continuing without great changes in its channel with stable regime. To appreciate their importance some example of rivers both in stable and in unstable regime will be considered in order to deduce the conditions and principles of their action; and by applying the tests found for these to the Irrawaddy delta the several phases of the hydraulic state can be discriminated. But the mass of silt yearly brought down is itself worthy of notice; and its amount and the method used in determining this are accordingly given, with estimates of its distribution within the delta and to the sea.

Method of determining total quantity of silt carried by the Irrawaddy.

45. The Myanoung gauge record for the whole of the years 1869 to 1877, for which the discharge has been calculated, was examined,. and the several stages of the river corresponding to the silt ratios marked approximately upon it. The discharges for these periods were multiplied by the proper ratio, and the results were tabulated. A correction of some importance was introduced. A cubic metre of water does not weigh exactly one ton; but at 60° Fahrenhert when pure it is not far from 55/56ths of it. It was not desirable to make any correction when the water was estimated, as the quantity is given by measure, and is directly comparable with data furnished from continental sources; but in taking the weight of the silt the results have been all corrected. It seems useless to attempt to give the amount of silt by measure, as its specific gravity varies much with the degree of closeness with which it is pressed together. It may vary from 2 to 3 times the weight of water. Table 16 gives the results obtained by taking a mean of the three ratios found for each stage of the river as the multiplier for the corresponding mass of the water. The figures given are tons by weight. The yearly average passing down the channel through the head of the delta is 291,429,252 tons. But it must be noted that this average is somewhat high as it is taken from a short period including four years of high flood. Assuming that somewhat less than two tons would make one cubic yard of solid ground such as is found in the delta, we have here a quantity which would cover nearly 150 square miles one yard deep brought down each year. Formerly the region now occupied by the delta was an estuary of the sea such as is found today at the neighbouring mouth of the Sittang; where bores of extreme violence rush up with each tide. Assuming the extent of this to be 12,000 square miles, and the whole of the silt to have been uniformly deposited over it, only 80 years would have been required to have covered it to one yard in depth; and even a conjectural depth of 100 yards for the whole area when covered by the sea would have been filled within 8,000 years, a comparatively recent geological period.

Distribution of the silt.

46. But it is manifest that a considerable portion of this silt is carried out far beyond the delta by the water; and is utilized in raising the sea bottom beyond. An attempt to roughly estimate the quantity is made in Tables 17 and 18; on the assumption that the greater portion of the lighter silt remains carried by the upper layers of the stream and is still in the water when it reaches the sea, and that only the heavier portion in excess in the lower strata is deposited on the way there. The river breaks into many branches in the region within tidal influence where it is at a level very little above that of the sea. Here it loses the continually impelling power of the surface slope; but, on the old Italian theory of Guglielmini, it receives a compensating influence in the deepening of the channels, which is common to all rivers in similar circumstances. But this influence appears only sufficient to enable the water to flow continually onward. Its excavating power has ceased or very greatly diminished, and the process of deposition has commenced. Inevitably the heavier and coarser matter must first fall; and, as will be afterwards shown, there is reason to suppose that this is still employed in raising and consolidating the lower parts of the delta. But from the known

slowness of deposit of the lighter silt even in still water this can hardly be parted with in any great quantity before the sea is reached. The latter Tables are thus founded on this distinction. Table 17 is calculated from the ratios of the upper layers only and gives the quantity of silt contained in the water reaching the sea on the assumption that it is all still there. The differences between the several quantities of this Table and of Table 16, represent approximately the silt left behind and contributing to the raising of the delta, and to its extension. These give an annual total of 115,163,871 tons of silt or somewhat more than one third of the quantity before obtained.

47. These figures have no claim to accuracy, and no practical importance is attached to them. They serve, nevertheless, to fix the ideas, and give definite conceptions of the magnitude of the operations in progress by the river itself. A clear idea of these operations, of the method and cause of action and the results, will be obtained by noting the outcome of the studies on a few other streams or rivers when exceptional opportunities have been afforded and have been availed of.

Table 16.

Shewing total amount of Silt in tons carried by the Irrawaddy in the years 1869—1877 found from a mean of the ratios I, II & III.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Totals.	
1869 ..	..	..	..	..	..	26,223,195	54,115,046	56,580,057	48,955,314	44,098,177	12,935,213	..	242,907,002	
1870 ..	1,474,032	1,156,615	1,020,542	1,232,329	1,618,239	18,019,282	62,702,851	64,263,735	59,471,107	30,523,813	10,037,889	6,468,944	257,989,378	
1871 ..	1,713,824	1,134,126	1,462,538	4,070,014	6,450,374	33,593,095	65,869,980	104,363,238	86,859,415	39,725,359	21,508,920	7,853,847	374,604,730	
1872 ..	4,964,328	1,469,020	1,342,337	1,408,172	10,571,163	15,867,682	59,511,543	64,358,062	52,924,311	55,755,030	16,584,071	7,278,110	292,033,820	
1873 ..	4,857,413	1,439,867	1,397,118	1,424,952	1,871,961	28,029,785	46,433,803	57,921,187	42,888,563	35,572,117	13,596,859	5,447,863	240,881,488	
1874 ..	1,449,156	1,039,800	1,402,697	5,178,209	13,754,400	15,227,013	49,818,436	45,506,043	51,197,975	43,889,150	13,433,716	5,939,157	247,836,752	
1875 ..	1,689,462	1,196,705	1,315,443	6,271,489	16,328,400	34,210,100	63,997,331	111,853,139	74,769,954	25,036,280	9,942,916	5,328,302	351.939,521	
1876 ..	1,439,559	1,008,105	1,333,532	4,269,974	4,652,146	21,035,520	60,555,410	67,214,781	26,774,926	23,197,466	9,842,853	5,177,956	226,502,228	
1877 ..	1,291,679	964,459	900,283	1,740,555	1,542,791	23,752,306	45,521,697	125,231,433	58,884,544	57,401,190	15,266,733	7,143,421	339,646,091	
Averages.	2,369,932	1,116,087	1,271,811	3,199,462	7,098,684	23,995,230	57,203,022	77,476,853	55,858,456	39,466,509	12,572,130	6,330,325	291,429,252	Averages.

Table 17.

Shewing amount of Silt found from a mean of the ratios I & II.

1869 ..	..	..	..	..	..	20,316,089	36,094,899	36,095,131	28,539,588	25,960,933	7,691,928	..	154,698,568	
1870 ..	650,811	494,190	436,050	526,540	691,430	13,960,235	48,578,370	38,476,427	33,687,882	18,588,943	6,320,136	4,073,031	166,483,985	
1871 ..	732,520	484,582	624,903	2,738.282	4,681,318	26,025,893	48,827,496	54,991,425	46,844,711	23,158,855	13,000,707	4,945,035	227,055,727	
1872 ..	3,125,685	627,672	573,544	601,674	8,189,886	12,293,358	37,242,526	37,519,003	30,853,412	32,503,638	10,441,834	4,582,509	178,554,741	
1873 ..	3,058,391	615,216	595,969	608,842	799,838	21,715,782	27,069,628	33,766,468	25,002,879	20,737,592	8,560,992	3,430,143	145,961,740	
1874 ..	619,185	444,279	599,334	3,611,112	10,656,059	10,999,977	29,043,368	26,528,780	29,846,991	25,586,165	8,458,262	3,739,466	150,132,978	
1875 ..	721,866	512,819	562,052	4,577,908	12,650,230	26,503,914	37,303,683	58,938,000	40,661,188	15,842,300	6,260,368	3,354,869	207,893,697	
1876 ..	615,084	430,736	569,782	2,956,390	3,142,477	16,296,936	35,302,144	39,181,358	16,858,307	14,605,828	6,197,342	3,260,206	139,417,090	
1877 ..	551,899	412,087	382,667	743,691	659,192	18,401,868	26,587,895	65,987,321	34,328,170	33,463,364	9,612,407	4,500,849	195581,410	
Averages.	1,384,430	502,635	543,038	2,045,554	5,183,304	18,501,561	36,222,779	43,498,266	31,847,015	23,383,066	8,496,886	3,935,764	176,385,171	Averages.

Table 18.

Shewing amount of Silt found from the differences of Table 15 and Table 16.

1869 ...	..	..	..	..	..	5,922,746	18,020,148	20,484,925	20,415,726	18,137,244	5,243,285	..	88,224,074	
1870 ..	823,222	662,425	584,492	705,788	926,810	4,059,047	14,124,472	25,787,308	25,783,225	11,934,871	3,717,754	2,395,912	91,505,326	
1871 ..	981,304	649,545	837,635	1,331,732	1,769,056	7,567,202	17,042,484	49,371,813	40,004,704	16,566,503	8,503,213	2,908,812	147,530,004	
1872 ..	1,838,643	841,347	768,793	806,498	2,381,278	3,574,325	22,269,017	26,839,059	22,070,899	23,251,392	6,142,237	2,695,600	113,479,089	
1873 ..	1,799,022	824,651	801,149	816,109	1,072,123	6,314,003	19,364,175	24,154,719	17,885,685	14,834,524	5,035,866	2,017,720	93,919,737	
1874 ..	829,971	595,522	803,363	1,567,097	3,098,341	4,227,036	20,776,068	18,977,263	21,350,984	18,302,986	4,975,453	2,199,691	97,703,775	
1875 ..	967,597	684,386	753,391	1,693,580	3,678,170	7,706,187	26,688,648	52,915,193	34,108,766	9,193,980	3,682,548	1,973,433	144,045,878	
1876 ..	824,474	577,369	763,750	1,313,524	1,509,574	4,738,584	25,253,266	28,032,923	9,916,619	8,591,638	3,645,511	3,888,215	89,055,469	
1877 ..	739,780	552,372	515,616	996,863	883,599	5,350,438	18,933,803	59,244,112	24,556,374	23,937,826	5,654,326	2,647,572	144,062,681	
Averages.	1,100,502	673,452	728,524	1,153,899	1,914,871	5,495,507	20,280,231	33,978,590	24,010,331	16,083,440	5,178,355	2,590,869	115,163,871	Averages.

SECTION III.

General discussion on the different parts of rivers, and their respective conditions.

48. Most natural streams are in a state of continual change in all their parts, and the most important of these changes are strikingly exemplified in torrents. M. Surell (1) has given elaborate and instructive studies upon the torrents of the higher Alps. He defines them somewhat differently from the ordinary mode, which considers them as streams of highly unequal discharge varying from states of almost dryness to great and violent flood. He makes them consist essentially of:—1st, *A basin of reception* in the mountains, which they excavate; 2nd, *A bed of deposit* in the valley where the excavated matter is dropped and on which they are liable to move from side to side; and 3rd, *A channel of flow* connecting the two former, and where the silt carried is transported without excavation or deposition. The channel of flow or trunk of a torrent is usually very short. The reception basin is more or less like a large funnel in the hills, with the gathering grounds for the rain-fall converging towards a common gully. In the steeper places the water is rapidly precipitated. Where the ground disintegrates rapidly, and is deprived of natural or artificial protection, it is cut up by the streams; and masses of earth, sometimes entire hill sides are moved bodily into the channel till the flowing water becomes a moving mass of viscous mud. The term saturation cannot be applied to the water, as it is possible to have every degree from almost solid matter to pure water flowing in the stream and passing to the plains. Where such excavations are in progress on any large scale, the régime of the reception basin is highly unstable, and no works of magnitude can be undertaken in the neighbourhood. Agriculture is ruined, and villages and populations imperilled. M. Surell deals at length with the remedial measures proposed for this state of things; and M. Cezanne adds a volume to his work in 1872, thirty years after that published by M. Surell, showing the excellent results following the adoption of these measures. It will be necessary briefly to revert to this subject in noticing the streams from the Pegu Yoma to the Delta of the Irrawaddy.

Distinction of the parts of torrent streams.

The reception basin.

49. The channel of flow of a torrent is the only portion in a condition of stability, and where permanent works of importance can be undertaken. It commences with the gully of the reception basin, and terminates at the exit from the hills to the plains, where the bed of deposit commences. This usually presents an analogy to a vast ruin with the debris of the mountains scattered around and in front of the gorge whence they issued. But a careful examination shows that beneath this apparent confusion there is a regular arrangement according to strict mathematical laws. The mass is like a cone-shaped counterfort with its summit at the gorge, and flattening out to the plains. It is wholly formed by deposits from the stream. Its slope is invariably greater in the upper part and gradually diminishes below. The stream on issuing from the gorge increases considerably in width on flowing over the flattened surface. This broadening and shallowing of the channel is a first cause of the diminution of velocity in the water. A second arises from the diminishing slope of the bed of deposit. From these two causes alone, acting together or independently, the course of the stream is checked, and a deposit of silt results. M. Surell has found that when the bed of deposits sloped sufficiently to permit a

The channel of flow.

The bed of deposit.

(1.)—Surell M. Les Torrents des hautes Alpes con une suite par M. Cezanne 1870-1872.

proper velocity to be attained, the narrowing of the channel flowing over it had the best effects on many torrents. It is a fact repeatedly noticed that the stream channel is constantly placed on the highest part of the bed of deposits. It is thus always liable to be diverted from its course, and to wander over the whole surface of the conoid in a short space of time. It tends to raise its own bed and banks and thus precipitates the change. This instability of the channel and of the substance on which it flows, renders the bed of deposits the very worst part of a torrent on which to undertake permanent works.

Necessity of regulating torrents.

50. After a careful examination of all the phenomena of torrents, both in their basins of reception and in their beds of dejection, M. Surell concludes that when the matter excavated in the hills is in excess of what the stream can dispose of without damage to itself, that is by carrying it to where it may be usefully employed in raising low ground, or by transporting it to other agents such as large rivers, &c., capable of taking it away, all works of improvement or protection other than stopping the excess excavating action in the hills are useless. This, and this alone, is efficaceous, by whatever means achieved. The matter excavated must be deposited somewhere; and it is in the agencies regulating both the excavating and depositing action that the success of many large river hydraulic works depend.

Resemblance of torrents to rivers.

M. Surell points out that there is a great resemblance between the phenomena of torrents and those of the largest rivers; the fundamental property of excavating, carrying and depositing belonging to all natural streams, though this is exaggerated in intensity in torrents, and is on a larger but milder scale in rivers. The deltas of the latter are directly comparable to the beds of dejection of the former when they enter the plains; the river channel is liable to wander over the delta just as it does over the deposits of the torrents. Rivers could, however, have no deltas were it not that they excavate their basins of reception. The two extremities of a river are thus terminated like those of torrents. But the channel of flow, that is, the trunk, which is nearly nothing in a torrent, constitutes almost the whole course of a river.

Distinguishing differences of rivers.

51. The general resemblance of torrents to rivers may be admitted; but each river has individual characteristics which discriminate it from torrents and from other rivers. The processes in operation are, however, the same, and it is only by obtaining an exact knowledge on what conditions each process, whether of excavation or of deposit, in every several case depends that we can attempt to prescribe with confidence the particular works required to modify and improve the state of any river. The phenomena of nature are here on so great a scale, and the forces operating so immense, that the utmost the engineer can do is to slightly assist or divert them, by taking advantage of every indication a careful study or the records of experience may furnish. The Irrawaddy works are almost wholly confined to the delta region, and are all dependent on the conditions generally affecting deltas; so that if it is generally true that a delta is altogether in a state of unstable régime, no expensive works of a permanent kind should be undertaken upon it. A detailed examination will show that while great changes in the main river are still in operation or threatened, and while other changes of a similar kind affect the portion of the delta nearest the Pegu Yoma hills, in many cases the consequent difficulties can be met or evaded, with some expense it is true, but with results which justify undertaking works of much greater magnitude than any yet put in hand. And, in some cases, particularly in that of the double embankment on the main channel in the upper delta, this power and facility of change in the régime of the channel is the principal agent to be relied on to bring the work to a safe conclusion. The very short time in which the Irrawaddy has been subject to exact observation, and the want of definite information on the various phases of the most important changes now in progress render it necessary to recur to the experience gained elsewhere, to permit the comparatively isolated facts at our disposal to be properly interpreted and to find their due place in a suitable explanation of their conditions.

The Hoangho.

52. The Hoangho is an example of a river where human effort has struggled for thousands of years, mostly unsuccessfully, against the forces of nature exerted on a large scale. The Chinese Annals and different accounts of the country describe the nature of the calamities and the remedies attempted. It appears that the river has been reduced to the condition of a gigantic torrent which brings down immense volumes of water excessively charged with silt in the floods and barely permits the passage of small boats in the dry weather. Its basin of reception is made up of numerous minor torrents and larger affluents in the north-east flank of the Thibetan Plateau, and in the smaller offshoot mountains extending to the plains. Its delta was formed originally in the nearly tideless Chinese sea, and now covers about 100,000 square miles and extends due north and south over nearly ten degrees of latitude. Whether the trunk of the river joining these was ever in a state of stable régime can now hardly be known ; but historical records prove that calamities have continually recurred through this part raising the bed and leaving the channel to spread over the whole country. In the delta this has frequently happened; the channel having passed over the ten degrees of latitude nine times in 2,500 years. On the last occasion, which occurred in 1851-52 and 53 the trunk of the river far above the delta also moved. The bed of deposit thus appears to have retrogressed from the true delta up the main river almost to its outlet from the hills like an ordinary torrent. This is entirely due to an excessive quantity of silt being brought from the reception basin and deposited in the channel. The Abbe Huc (1) describes the condition of this in 1843. He says, "that for more than two hundred leagues the river flowed in a channel higher than the surrounding plains of the valley. It is always being raised by the immense quantities of silt brought by the river ; and it can be seen that a frightful catastrophe is imminent." Mr. Ney Elias (2) surveyed the river in 1868. He found that the calamity predicted by Huc had occurred. The river had cut out a new bed for itself. Its course was spread over 10 or 12 miles in width of its own silt. The richly fertile district of a few years past was a mass of sand and sediment, presenting a scene of dreariness and desolation. Nearly deserted villages were almost buried in the mud. At one spot where he measured this, it was over 13 feet thick, formed by 15 successive flood deposits. The abandoned bed of the river stood high above the surrounding country. Here the conditions to which the non-success of the remedial efforts were due were clearly indicated. The water from the mountains brought down a higher ratio of silt to the river than this could carry. The efforts of the Chinese had been mostly directed to embanking the sides of the channel to prevent spill from floods. Either this channel had been too broad and shallow, or the general slope of the country is not sufficient to permit it to generate energy sufficient to carry off all the silt brought down. If neither of these conditions can be made efficient, the only remedy available is to stop the ravining of the torrents in the mountains. Possibly this may be in a measure due to disforesting and denudation of the natural coverings of grass and herbs on the slopes in the lower mountains, which are likely to be the immediate sources of the evil, but it is clear that until this is stopped the silt brought down must continue to deteriorate the river, either in its upper trunk or in the delta, by unduly prolonging it in the sea. The conditions of this river make it evident that the largest river is liable to deteriorating effects from sediment, and that these may pass backwards through the whole course of the river to the hills, rendering all useful works impracticable in its neighbourhood.

The Po.

53. In contrast with this complete instability of régime in a great river, the Po offers one of the best examples of general stability, side by side with such variations of condition in parts of its course or of its influents, as have led to a general denunciation of all protective works like embankments, on the channels of great rivers.

(1.)—Huc L'Abbe. Voyage dans la Tartarie.

(2.)—Elias Mr. Ney. Journey on the new course of the Yellow Rivers in 1868. Journal of the Royal Geographical Society 1870, Vol. L.

Many of the conditions affecting both the stable and the deteriorating condition of that river have been cleared up by the distinguished Engineer, the Commendatore Lombardini, in a series of memoirs commenced in 1840 by a paper " on the hydraulic condition of the Po," and continued till with in the last few years. These memoirs form an invaluable repository of information on the most important points of river hydraulics and present a comprehensive discussion on the principal questions connected with embanking, and with natural and artificial changes induced in the régime of rivers. He was peculiarly fortunate in having classic records open to him in which he could trace from precise data some of these changes ; and the numerous memoirs and controversies of the eminent Engineers of Italy permitted him to establish his conclusions from well recognized facts. These treatises have been published in three separate collections, which include papers and reports by hydraulicians of the highest renown, such as Leonardi da Vinci, Galileo, Torricelli, Guglielmini &c. There is thus a continuity in the studies, extending over several centuries, which gives a value to Lombardini's writings, independent of a clearness and beauty of their own in the presentation of results, and which render them particularly interesting to the practical Engineer who wishes to derive illustrations of hydraulic principles in action for his own guidance.

54. The leading idea through the whole series of Lombardines memoirs is to ascertain how far certain statements made by Cuvier and others relating to the Po are well founded. That writer said in his discourse on the revolutions of the surface of the Globe, " it is manifest to every one how in Holland and in Italy the Rhine the Po and the Arno, through being embanked, elevate their beds and advance their mouths to the sea." These words have formed the text for many discourses against embankment works, sometimes well founded, in others not so. Cuvier's views regarding the Po were founded on those of the Baron De Prony, who was deputed by Napoleon I to examine projects for improving the lower part of the river, then in an acknowledged state of deterioration in certain parts. He reported that the Po had so raised its bed since the epoch when it was embanked that the surface of its waters was then higher than the house roofs in Ferrara. He said "The Adige and the Po are higher than the intervening ground and it is only by opening for them new beds in the low parts which they formerly deposited, that the disasters which menace them can now be prevented." These charges against embankments are general and indiscriminating ; and, if true, are such as to prevent this kind of work from being often resorted to.

Statement of Cavier that the Po and other rivers raise their beds.

55. Lombardini takes up the several part of the river separately and examines them. The Po runs from west to east over 250 miles to the Adriatic. It lies between the Alps to the north and the Appennines to the south. Its basin of reception is made up of that of its principal branch west of Turin and of the several basins of receptions of its influent streams. The tributaries from the Appennines are all torrents. Those from the Alps are divided into two classes, torrents and lake rivers ; the former are turbid, the latter limpid. These lake rivers generally flow in beds deeply excavated in the ground ; the torrents have their banks always, and their beds often, above the surrounding country. This distinction is entirely due to the ratios of the silt carried by the different streams ; the lake rivers having deposited most of theirs in the passage of the water through the lake, and being ready to excavate afresh on issuing from it. The Alpine torrents are more highly charged with silt than the southern ones, and their immense deposits have pushed the main trunk of the Po towards the outspurs of the Appennines in the higher parts of its course

Lombardini's investigations. Influents of the Po.

56. The main channel of the river, like those of its torrent influents, has its banks raised above the surrounding country by the spill water of the flood throwing down its silt immediately on leaving the channel. The banks thus form natural embankments which partially protect the country on the sides,

Main channel and Embankments of Po.

but when the flood passes over them it lies on the lower country. In this the Po resembles all silt bearing rivers, and similar characters are found on the Irrawaddy, and on all the minor streams in the delta. The embankments of the Po are built on this elevated ground lining the river channel. This enters the plain land about Cremona ; above which place there are small isolated embankments, and below it are continuous embankments connected into one solid system to the sea. This consolidation only took place about the middle of the 16th century; but above Ostiglia it appears they were perfected about the year 1300. For about 150 years previous to this century the main works remained unbreached, and without notable changes. They thus permit accurate indications to be drawn as to whether the channel of the river has deteriorated since the construction of the embankments.

Facts influencing flood levels of rivers.

57. Lombardini first shews that the flood levels cannot be taken as data on this question. These are liable to changes from two causes, one of which is independent of the construction of protective works. Firstly they are liable to variation from changes in the state of the reception basins, which follow the increase of population or the spread of cultivation. He states that the forests which clothed thickly the slopes of the mountains exercised a most beneficial influence in protecting the loose soil by their roots, and by sheltering it from the showers. This and the trees themselves stored up a portion of the water and discharged it gradually or permitted it to re-evaporate. This view as to the action of trees has been disputed ; but the balance of high authority is in favor of it. There is, however, no doubt open that the grass and herbs of the mountains do protect the soft surface soil, and one of M. Surell's principal remedies for the evils of torrents is to foster the growth of these. It is in any case a recognized fact that as the gathering grounds of the floods are occupied by settlers they come down more rapidly, and rise more acutely in the river channel, at the same time that they bring down both increased quantities and higher ratios of silt. On the Po these effects are proved to have happened. The second source of change in the height of the flood is due to the embankments. The spill water which inundated the low country on both sides of the river in its unprotected state is gradually shut in to the main channel as the embankments are extended and perfected. The additional burden must thus raise the surface in floods, but, as will be shown, this tends to increase the excavating action of the river on its bed, and ultimately to enlarge the channel.

Low water test of changes in the elevation of river beds.

58. The test the least open to objection is to be found in a comparison of the low water levels of the river from time to time. This shows whether the bed of the river has been raised or lowered, the former effect being the principal source of deterioration. To do this properly the quantities of water discharged should be known and the surface levels compared ; but as no such data were available for the earlier times, it was only possible to examine the height of the extreme lowest floods upon record as marked at different places. The first branch of the Po breaks off at Stellata, and Lombardini investigates the changes in the trunk of the river above this place, from datum points at different towns. He finds that though the works were mostly constructed on this part by the 12th century, no changes of importance have occurred in the height of the bed since that time. There have been slight variations of level of a few decimetres at one or two places ; but at others no change has occurred. In the trunk of the river below Stellata, which may be said to be in the Delta of the river, changes have occurred since the construction of the embankments; but it appears that while both the low water levels and the flood levels were lower at the end of the seventeenth century than they are now; they are at present lower than they were about the year 1600. This change Lombardini ascribes to the closing of the Po of Ferrara, which compelled an increased discharge to flow in the main Venetian branch. His statement as to the mode in which this occurred

The effect of embankments on the bed of the Po.

is remarkable, as showing that he, contrary to most hydraulicians at that time, believed in the pressure theory of the flow of water. He says "When the water of a river or canal moves owing to the fall of its bed, its velocity is greatest near the surface and least near the bottom, through the resistance found there. But when pressure predominates in causing the motion in a stream. the velocities increase from the surface downwards. This phenomenon may be seen occurring between the piers of a bridge, when the opening is so narrow as to cause regurgilation." In a note he describes how he himself had observed this twenty years before. He applies this law to explain the excavation of the bed through the increased depth and pressure caused by increasing the discharge in a narrow channel. An operation of this kind resulted in lowering the bed of the Po at Ferrara in the 17th century; but this deepening has again been lost by :—1°, the river having increased in width; 2°, the prolongation of its mouth in the Adriatic. He finally concludes that notwithstanding these local variations of level, the bed of the Po on the whole is lower at present than it was before the embankments were constructed; notwithstanding its greater flood discharge, and the larger amount of silt brought down by the torrents.

Lombardini on the influence of pressure on the flow of water.

59. This conclusion embodies one of the most important principles of river hydraulics; the one relied on as indicating the most efficient agent for promoting the ultimate success of the embankment works of the Irrawaddy. It will thus not be out of place to bring forward other testimony of not less importance, derived from experience on other great rivers, though from data extending over a shorter time. M. Baumgarten describes (1) some works executed on the Garonne from 1837 to 1846 to regulate its channel and protect the riverain lands. These extended over a length of about 18 miles on both banks in the same part of the channel, and were designed to improve the navigation, to protect the banks from erosion and to preserve generally the surrounding lands. The most careful observations were made throughout the progress of the works both on the quantities of water discharged, and on the levels of the river surface at different points of its course. The results are given in complete detail in M. Baumgarten's Memoir, with plates. From the whole of these he makes it clear that the protective works have resulted in a lowering of the low-water surface in the part where the works are, while it has remained the same in the portion of the river beyond. At first the river channel was narrowed by the works. This was immediately followed by a raising of the surface about 16 inches. But the water quickly excavated the bed and a definite and permanent lowering of this from 2 feet to 2 feet 8 inches was established, which still continued in progress when he wrote. The high flood discharges were little influenced by the changes; but there was reason to suppose that the mean flood discharge would have been raised about $2\frac{1}{2}$ feet if it had not been for the excavation of the bed.

The embanking of rivers tends to improve their channels.

Baumgarten on the Garonne.

60. Extensive works for the regulation of the river channel and for the protection of the land on its banks have been carried out by the different states on the Rhine. During the present century they have acquired a completeness which permits their effects to be seen. (2) Herr Grebenau has taken two periods of 33 years each, from 1807 to 1839, before the works were systematised and perfected, and from 1840 to 1872 inclusive, since that time. He compares the records of the river gauges at Strasburg for these two periods. Taking the mean monthly and yearly gauge readings he finds that at Strasburg the mean of the whole has been lowered about one foot (30 centimetres) as a consequence of the protective works. He finds also that the low water surface

Grebenau's account of the results of the Rhine works.

(1.)—Boumgarteu M. Notice per la Garonne 1849.
(2.)—Grebenau H. Resultate der Pegelbeobachtungen an den Rhine and Mosel Strasburg 1874, von 1807 bis 1872.

has been lowered about 20 inches (50 centimetres), which implies a corresponding lowering of the river bed. But the highwater level in floods has been raised about 6 inches. This, as explained by Lombardini, is due to the more rapid arrival of the rainfall, and to the increased discharge consequent on embanking and shutting in the spill. Probably the further deepening of the bed will eventually lower the high flood level also.

Abbot on the effects of embanking rivers.

61. General Abbot, one of the authors of the Mississippi Report, writing as Secretary to a Commission appointed by the United States Government to consider a general plan for the reclamation of the basin of that river, says (1) in 1875. "It is claimed, since the effect of embanking a river is to confine its sedimentary matter to the channel, that the deposit formerly made on the banks must settle on the bottom, and then ultimately raise the bed, and with it the high water mark. This idea, utterly without foundation in theory or experience, is usually defended by appealing to the example of the Po, which is asserted to have raised its bed several feet. In point of fact such is not the case. * * * The most careful measurements upon the Mississippi have failed to detect any indication of a filling of its channel by levees." He shows that the channel of the Mississippi flows in hard ground, and that there is little hope of its scouring out a larger section; and that the practical effect of the embankments will be to raise the flood surface of the river, which must be met by strengthening the embankment works. He considers that the prolongation of the Delta into the Gulf of Mexico which is steadily going on will have no injurious effect in raising the flood surface of the river. "Simple calculation will show that hundreds of years will be required to raise the flood height at New Orleans one inch from this cause."

Testimony conclusive that embankments do not cause an elevation of river bed.

62. These statements must be accepted as decisive regarding the result of embankment works on the main trunk of a river above the bed of deposit, or delta. The bed is never raised; but, when the material is easily moved, is invariably deepened. The low water level is reduced and the navigation improved. The high flood surface is invariably raised at first, but when the bed and banks are excavated may ultimately be again lowered; and this usually takes place in soft alluvial deposits. Embankments and other works may therefore be made with confidence in this part of a river, provided they are strong enough to contain the floods; and are sufficiently removed from the edge of the banks to avoid falling in through the corrosions of these.

Protective works in a river delta.

The delta of the Po.

63. The Delta itself, the true bed of deposit where the silt brought down from the basins of reception must ultimately fall, has yet to be considered. Signor Lombardini points out that the channels of the Po have varied very much within historical periods, over the delta; and that many works of man—cities, roads and embankments have been rendered useless, and abandoned. But reclamation works of a most extensive kind have been profitably carried out within the delta, partly by filling in low swampy ground by the silt from torrent streams, partly by reclaiming the swamps by embankments and drainage works. One of the most important of these, near Ferrara, is still in progress, and vast sums of money are being expended, and the highest resources of mechanical art employed, with every prospect of profitable returns. The protrusion of the mouth of the Po in the Adriatic continues unceasingly, and is due to the silt brought down by the river, which Lombardini estimates at the enormous total of 40 millions of cubic metres yearly. This is deposited over the gently sloping bottoms of the Adriatic in front of the delta, and contributes to the formation of new land. Whether this is attended with deterioration of the upper channel owing to the consequent loss of slope is difficult to say; but appears improbable.

(1.)—Abbot General H. L. Report of Chief of Engineers 1875, Part I, p. 548.

64. One of the worst examples of deterioration due to the advance of a delta is probably found in the Rhone. In a note communicated to General Humphreys, Chief of Engineer of the United States (1), M. Malezieux pointed out that an attempt to improve the entrance to this river by removal of its bar through scouring was attended with failure. The whole of the divided discharge of the river was compelled to flow in one channel by running jetties on the sides of the mouth. This was effected in 1856 when the depth of the water on the bar, which had previously been 5 feet, was soon increased to 13½ feet. But, as the sediment brought down was concentrated on a smaller area, the sea in front of the bar was rapidly shallowed, and a new bar formed. The rate of advance of this yearly was 290 feet, while that of the old bar was only 76 feet. It was found inexpedient to continue the advance of the jetties at the new rate, and the river reverted to its former condition at this mouth ; while a ship canal was opened laterally. General Humphreys uses this illustration in support of his views condemning the present attempts to improve the entrance to the Mississippi by similar means. This work was undertaken at the South-west Pass, and consists of parallel jetties narrowing the channel and causing the water to scour out the bar, which had a depth of only 7 feet of water upon it. This bar advanced into the sea at the rate of 100 feet annually; and the Committee recommending the work assume that the rate of advance will continue the same after the work is complete. But General Humphreys shows that this assumption is groundless. The entrance over the new bar will be very much narrowed to 700 feet, and its rate of advance increase to probably 600 feet a year instead of 100 ; and that the least probable rate of extension to be expected will be 450 feet annually. This must ultimately exceed, in the cost of the works required, all reasonable limits, and General Humphreys recommends a lateral ship canal to be substituted, where the deposit of silt can be hindered by locks.

The delta of the Rhone.

The bars of the Mississippi.

65. The case of the Sulina Mouth of the Danube has been cited as one where the improvement of an entrance has been successfully carried out by similar works. On examination it is found that although the Danube is a silt bearing river, the bar is here mostly due to littoral currents; which also carry away the silt brought down by the water. This feature seems the distinguishing character which discriminates the states of rivers into improving or deteriorating conditions, whether in torrents or in large rivers, both in their trunks, and in their deltas. Lombardini repeatedly states that the increased volume of flood waters and the concentration of the energy in them owing to embanking is the principal cause of the Po not having greatly deteriorated through the increased quantity of silt brought to it during recent times by the torrent streams. The river can thus carry it off to the lower delta and to the Adriatic where it is usefully employed. The sea and ocean currents appear unable to remove the silt brought down by the Rhone and the Mississippi from the immediate neighbourhood of their mouths, and it is thrown down directly in front of the deltas. The Hoanghor is not only unable to pass all its alluvium through the trunk to the shallow Chinese seas ; but the absence of strong littoral currents here cause all that has reached them to be at once deposited and the channel of the river lengthened. It is thus found that the requisites which M. Surell demanded for torrent streams are necessary for rivers in good condition ; 1st—The quantity of silt excavated in the reception basins and brought to the channel of flow must not be more than this can carry away ; 2nd—The trunk of the river must have a sufficient slope, and be of a proper shape to permit the development of sufficient energy to remove all the silt brought to it, to the true bed of deposit ; and 3rd—The bed of deposit must be such as to be capable of receiving the silt brought to it without injury or with improvement to itself ; or there must be some agency such as a large river for torrent streams, or ocean currents for

The Sulina mouth of the Danube.

The value of littoral currents.

(1.)—Humphreys General A. A. Report of the Chief of Engineers 1875 I, 974.

rivers, to remove all the silt in excess of that which can be usefully employed on the bed of deposit, or true delta. When either of these conditions fails the river is in a state of unstable régime, and is deteriorating; and any protective works which do not bring a sufficient remedy in themselves may be injurious, and are likely to be unsuccessful in their aims.

Criteria established for judging the condition of a river.

66. We have now some criteria established by experience from which to judge of the condition of the delta of the river, and the operations in progress upon it. This must not be considered as a finished work of nature delivered from her hands to be operated upon independently by man. It is still in process of formation, and all the laws regulating that process in this part are still valid, and the agents are in full activity. It is only by studying the mode of operation of these in each case as it arises, that the best solution of the problem can be suggested, and as it is more or less according to the views held by different engineers on these modes and processes that the different remedial measures proposed by them are founded, often, as will be seen in the case of the Irrawaddy, widely at variance with each other, a closer examination of some of these views will be given as briefly as possible before reviewing the features and various problems presented in the delta of this river.

On the excavation and removal of earth by water.

67. The process of excavation of the earth by the water and its subsequent deposition as silt are hardly considered matters for doubt. Even when stationary, water may loosen adherent particles of earth by chemical or mechanical action, and thus facilitate their subsequent removal. When in motion water acts mechanically by imparting a portion of its stored up energy to the matter moved by it, whether in mass or in small sub-division. The fluidity of the water enables it to move downwards under very small impulses from gravity, which would be insufficient to cause motion in the particles of earth *in situ*; and even when these are being carried along by the water in its course, the effect of gravity would be to make the silt descend to the bottom of the stream if some share of the accumulated energy in the moving water were not transferred to it. This transference may be through impact or percussion of the particles of the water upon those of the earth, or by friction; but the result is always the same, an amount of work has been done by the water upon the matter carried. In natural water courses the power of doing work arises from the fall of the water from where it has been elevated by the sun as vapour, when it possesses so-called potential energy, which it gives out in its descent to its ultimate lowest receptacles. When it descends in very small streamlets a great fall in a short distance is requisite to enable the water to acquire sufficient actual engergy to move the loose earth; but in large streams an infinitesimal fall suffices to generate very great velocities in the water, and an energy corresponding to these velocities is used up in performing work on the contiguous ground. In all cases where earth is moved by water, whether in the original excavation, or in its transportation, there is work being done and energy expended; and an equivalent amount of energy must be in course of generation by gravity through the surface fall and the pressure of the upper on the lower layers of water (or to use words similar to these accepted by advocates of the surface fall theory, by the surface fall and the shape of the channel,) or the motion ceases and the suspended matter falls. The deposition of sediment in the conoids of torrents and of river deltas is solely due to the cessation of this development of energy through the gradual loss of slope in the water surface.

On the silt carrying power of water

68. While the first excavation of the earth and its final deposition appear susceptible of easy explanation, there is some doubt as to the method by which silt is transported in the intermediate stage, on the trunk of the river, by running water. Experiments have been made which prove that all or nearly all the turbid matter in mechanical mixture with water will settle to the bottom after a certain

time, according to the different degrees of fineness, when this is in a state of rest. Various theories have been emitted to explain why it does not settle in the same manner in flowing water. One of the earliest is that of Leonardo da Vinci, who after explaining the excavation and deposition of silt in a similar manner, but in different terms, with the above, proceeds to say (1) that "when the water has greater motion it carries a greater quantity of earth with it" "and reciprocally" "when the motion diminishes the water disburdens itself of silt." This, perhaps, is not sufficiently explicit, as it opens room for a view of his meaning represented in the following extract from a memo. by General Humphreys (2).

Leonardo da Vinci's views.

He says:—"The explanation usually given for the formation of a delta bar is that first stated, the sudden and great check the current receives upon entering the sea, which causes it to drop the greater part of its suspended matter. In connection with this explanation it has been sometimes stated that every velocity of current is capable of carrying in suspension a certain fixed quantity of earthy matter, and that the water of a muddy river is always thus charged with the maximum quantity of earthy matter it can carry. If this were true, then if the current were suddenly and largely checked upon entering the sea, a large part of its earthy matter would be let fall and would go to the formation of the bar. But this assumption as to the carrying power of currents is utterly disproved by long series of exact measurements upon the Mississippi river. These measurements show that at no time has the water been so heavily charged with earthy matter that the current could not carry it along in suspension to the same extent as it did when the quantity of earthy matter was least. And they further show that the current of the Mississipdi river, when most feeble, can carry in suspension the greatest quantity of suspended earthy matter found in it, to the same extent that it can carry the least quantity found in it. It was undoubtedly the observation of facts similar to these that led to the conclusion, entertained by some, that the suspending power of the current of a river did not depend upon its absolute rate of motion, but upon the differences of velocity between the adjoining fillets of water. There is good reason to conclude that this is one of the causes or sources of the suspending power of a stream."

General Humphrey's views.

69. The view last adverted to was first enunciated by M. Dupuit (2). He quotes M. Minard who says that the sand can be seen moving at the bottom of a clear and shallow river in the direction of the current; and he cites some facts regarding the transport of great masses of sand and gravel on the bottom of rivers, and also thrown up in floods on top of cultivated land. This last he remarks could only have happened if the solid matter had been in suspension in the water, and he proceeds to enquire on what principle this power of suspension depends, and how far it extends. He shows that if solid matter like sand or gravel be placed in a vase with water, which is made to revolve, the heavier bodies are carried up in the water in proportion as the velocity of this augments. He observes that this cannot be due to the absolute velocity of the water, as even in a stagnant tank the water is carried round by the motion of the earth faster than the swiftest torrent streams flow. He thus finally gives expression to his theory. "The difference of velocity of the fillets, in making unequal currents pass to the right and to the left of the body, engenders a force which pushes it to the side of the more rapid fillets. Experience comfirms this every day; we see floating bodies detach themselves from the side of the banks, and place themselves in the axis of the current. If now we imagine a solid body plunged into the current, we would recognise that the relative velocity of the fillets in the vertical direction will engender a presure which will carry it to the side of the more rapid, that is it will act from below to above. This pressure may be more feeble than the weight of the body, which

M. Dupuit's theory.

(1.) Humphreys General, Report of Chief of Engineers Washington 1875 p.
(2.) Dupuit M, Etudes sur le Mouvement des Eaux 1863.

will then descend until it encounters a couch where the pressure is equal to the weight; which will necessarily happen where the current is deep enough, for in proportion to the depth, the velocity increases, and with it the upward pressure. If on the contrary, the pressure is stronger than the weight of the body it will raise it into the layers which, although having greater absolute velocities, have more feeble relative velocities, so that the solid body is arrested at a certain height."

General Simpson's exposition of different theories.

70. There has been an immence accumulation of experience in practical river hydraulics in America, and one of the ablest practicians, General Simpson, in charge of the Upper Mississippi improvements, thus records some of the generalizations regarding this question of the silt carrying power of water, which is the cardinal point to be attended to in the explanation of many of the phenomena, and in actually designing river works. He says (i):—The transportation by running water is a topic that has been often discussed and many theories advanced to explain the facts. The discrepancies of the theories even now held by different writers is proof that the facts have not been collected and studied to a degree justifying any statement being put forward as absolute truth * * * a shade of the truth probably pervades all the theories, but mixed with much error, arising from their having been based upon the study of a single stream, and that presenting probably extreme conditions. From France comes the theory of the controlling influence of breaks in the continuity of the direction or in the changes of direction; from India the theory that water flowing between banks or over beds of loose material, carries a load of sediment, bearing a fixed ratio to the velocity and subject to modification by depth, and, of course, the character of the material carried. Briefly stated, in a river flowing in a bed whose material is uniform, the amount of sediment borne varies directly as the velocity and inversely as the depth; and that the water passing any section is always charged with the full amount of matter it is capable of carrying. Consequently, the load borne varies with every change of velocity, however slight; dropping a portion of the load when velocity is diminished from any cause, producing sand bars, and recovering its load by attack on the bottom or banks where the velocity increases, resulting in erosions; while with a uniform velocity, neither erosion nor deposit can take place. According to this theory, uniform motion, with its attendant saturation with sediment, should be the object. According to the impact and friction or change of direction theory, deposits are inevitable if sediment is borne, and erosions must occur if the angle of impact exceeds a limit proportioned to the resisting power of the soil, consequently according to this theory, the object is to diminish the amount of material in motion, to prevent deposits, and to check erosions by protecting the banks exposed to attack and to prevent the occasion for injurious action by securing an unbroken continuity to direction, and reduction of the angle of impact by regulating the outlines of banks to a succession of osculating curves. Experience has shown that practice under the latter theory is attended with success. The former theory rests upon observation, but has not been tested by practical works for the improvement of rivers based upon the principle given."

Mr. Login's theory

71. General Simpson (1) gives a case where the Missouri muddy water joins the clear water of the Mississppi and the two streams flow side by side for many miles without intermixture; and without apparent change in the quantities or ratio of silt carried, though changes take place in the velocity, and in the shape of the bed. He states that Mr. Login, the author of the Indian equilibrium theory first described, appears to have lost sight of the fact that large quantities of matter may be held, the capacity for which varies for different soils; "also of the fact that the capacity of a stream to abrade is mainly due to the living force (MV^2), a function of its mass and velocity; and that the factors may change and the

(1.) Simpson General. Report of Chief of Engineers Washington 1875.

product remain the same. The resistance to abrasion depends upon the nature and shape of the banks and bottom."

Summary of views and facts.

72. The various views above given present not only the explanatory conception of the principles of the different writers, but some of the principle facts observable in silt bearing streams. Thus it is a fact that in almost all stages of a river, and with all velocities of the water, where this moves over soft alluvian lining the channel, there is a contant stirring up of this matter, and a process of transference of the lighter particles down stream. In the more violent floods immense masses of earth, and sometimes large rocks, are bodily transported. Co-existent with both the gentle and the violent action of abrasion there must be a continual re-deposit of the surplus matter thrown into the stream. Observation of any natural stream demonstrates that these processses of excavation and re-deposit are continuous from one end of the trunk of the stream to the other; and these facts are as well attested as the presence of silt in the flowing water. The heavier alluvion is transported, or, as it were, rolled along the bottom of the river, sometimes in great masses, but always at a slower rate than that at which the water itself flows. There is thus a well-observed series of facts co-existent and connected together; 1°—The presence of varying degrees of silt in the water of soft alluvion-lined streams, generally carried along with it in a diffused state at much the same velocity as the water: 2°—a continual excavation and re-deposition of the softer material of the bed and banks: and 3°—a continual transport of masses of alluvion by rolling along or near the bottom at a lower rate than the moving of mass of water.

Examination of the different views.

73. In examining the views explaining these facts it may be accepted as proved by observation that the quantity of silt carried by a stream does not depend directly on the velocity alone of the current, or that all streams are saturated with the utmost amount they can carry. It is hardly probable that any person intended the theory to be understood in that form. Read by the light of the context both Leonardo da Vinci's and Mr. Login's views are susceptible of a wider interpretation. If a stream be conceived with all the layers flowing with the same velocity in parallel lines there is no reason apparent why the lightest silt should not sink to the bottom in just the same time as it would do in still water, whatever that velocity might be. And, indeed, it is not quite clear how M. Dupuit's views can be held sufficient to explain all the phenomena. It is true that in every case the velocities of the different parts of a stream vary from one thread, where it is the maximum, to smaller degrees of speed at the sides. But there is a greater difference between the contiguous fillets on a vertical line in a slow current than at the time of great floods. On almost all the great rivers where the velocities have been systematically measured the vertical curve of velocities is more nearly upright at great speeds than at slow ones; that is, the relative velocity diminishes. The ratio of silt carried, however, is generally higher in flood than in the low water stages of the river, as the Irrawaddy measurements show. And on this river the curve of velocities sometimes varies very little at high flood from the surface to the bottom, though the ratio of silt carried does not diminish. The explanation fails with the majority of the facts observed; for, while it is probable that so far as there is a difference of velocity in neighbouring fillets of water, that difference may have a tendency to counteract the effect of gravity on the silt, this tendency must be exceedingly small and quite inadequate to produce the whole of the facts known to exist. Even the carrying of the floating matter from the sides to the thread of a stream may be otherwise explained, than by the relative velocities of the surface. M. Fargue in his interesting study on the results of the works carried out on the Garonne (1) shows that the ordinary hypothesis of the flow of water in parallel fillets is absolutely inapplicable to rivers. The whole of the ob-

M. Fargue's studies on the Garonne.

(1.)—Fargue M. Etude sur la correlation entre to conjiguration du lit et la propondure he lan dans les rivieres a fond mobile 1867.

served facts proves that there is a reciprocal interpenetration of all the fillets throughout the section. The particles of water successively strike against the banks and bed and are diverted from their direction by the shock which is propagated transversely through the current. The transmission of movement is not instantaneous, but is communicated slowly. From the hypothesis based on this interpenetration of fillets, M. Fargue deduces an explanation of many of the phenomena of excavation and deposit of silt by a current, and of the co-relation of form between the banks and bed. It is sufficient here to note that all the facts on record bear out this view. In the more violent impacts of a stream on the bed or bank large whirlpools or smaller eddies are formed, which sometimes take up masses of earth bodily and transpose them; as the wind is often seen to do on dry land. And in a minor degree the same effect is observable with gentler currents. All action of the water in channels with moveable lining is attended with commotion in the neighbouring layers of water. These carry with them, often to remote distances, the particles of earth loosened by the action. This result is attained by the continuous impact of the faster flowing particles of water on the slower moving heavier matter; a direct communication of energy, or rather a performance of work, overcoming the action of gravity takes place, which is achieved through the expenditure of energy by the water.

The reciprocal interpenetration of fillets.

74. Leonardo da Vinci bases many of his statements and practical recommendations in river hydraulics on this theory of impact; and, though the terminology and manner of expression of the present day do not always accommodate themselves to his language, there can be little doubt that the substance of his hypothesis agrees in much with the latest views on the subject. More precisely he speaks of a heavy solid B in a stream which cannot move unless by the precussion of the contiguous water, which by its motion, blows and friction *(moto colpo e confregazione)* roll it along. The whole context of his work shows that he considers the velocity as a measure of the power of performing work, a power which is in continual operation by the water in a current (under the names *impeto* and *potenza*), and that, when the velocity diminishes, this power of carrying silt also diminishes, and a deposit occurs; the converse of both facts being true. Read in this light the following explanation of the series of facts above recorded may be connected with his words. The water in the trunk of a silt-bearing river-current is generally in a continual state of excavation or deposition on the looser lining of its channel. A portion of the matter removed is transferred bodily, with only partial diffusion in the current, and it moves at much slower velocities than the water moving it. The remaining matter moved is diffused through the current continually by the eddies and whirls and interpenetration of the fillets of water; and it is principally to this interpenetration and repeated coursing of the particles of water throughout the current that the presence of silt in the upper layers of a stream is due. Were it not for this continual circulation, the silt would descend to the bottom in just the same time as it would in still water; and without re-excavation it would remain there, the water becoming gradually purified. Both in the excavation and in the diffusion there is an amount of work done in overcoming the action of gravity on each successive section of the river. The whole of these sections taken together make up its course; and the work done is restored by the action of gravity on the water in descending the trunk of the stream.

Extension of Leonardo da Vinci's theory, in accordance with later views.

75. It is necessary to discriminate here between the total energy residing in the moving mass of water in a stream at a given section, and the moving force at the same place. The former is, as stated by General Simpson, approximately proportional to MV^2, where M represents the mass, V the

On the work done by a stream of water.

mean velocity of the water, moved per second. This represents the stored up energy, the capital so to say of the moving water, which cannot be drawn against without a loss of power to the stream and a consequent deposit of silt. Such losses occasionally take place; and, also, corresponding increases, attended by renewed excavation; but when the motion is uniform on a given length of channel the moving force of the stream is quite independent of the energy MV^2 residing in it at the time, and depends entirely on the form of the sections and the surface slope of the stream. The same moving force would be generated, the same work performed by gravity on the same mass of viscous liquids like oil or treacle flowing slowly through the same channel whatever their velocity of flow might be provided their weight was the same. This moving force on a given section of a stream is called by Rankine the *dynamic head.* It is proportional to the mass and is a function of the velocity which would be generated by gravity in a given time, such as a second, on the flowing water were it free to act; that is, if there were no corresponding resistances offered to the stream in that time. If N be that velocity, then the dynamic head is proportional to MN^2, which is entirely independent, as said before, of MV^2, and which is thesole force available for overcoming the resistances on a uniformly moving stream.

The living force and the dynamic head of a current.

76. These resistances arise from the internal and the external work done by the water. In uniform motion they are together equal to the moving force or dynamic head, and use up in work the force generated by this simultaneously with its developement, leaving the total energy of the moving water MV^2 untouched and unchanged. They are, however, a function of this energy, both separately and together. The distribution of the dynamic head between them depends on the nature and condition of the lining of the channel in which the water flows, using here the word lining to mean the sum total of the contiguous surroundings. For ordinary purposes its meaning is restricted to imply the more solid matters immediately acted upon or touched by the water. When these are wholly incapable of suffering any change from the flowing water, no silt is carried, and no external work is performed; the whole energy generated by the dynamic head is used up in internal work consumed by the flowing water in heat producing commotion, or in the so called friction of the particles of water gliding past each other. But when the lining of the channel is susceptible of such change, this is moved by excavation, transport and redeposit through the external work performed by the water; and all the dynamic head not required for the mere flow of pure water must be used up in external work of some kind or other in natural channels. Very often this fact is lost sight of in river works. A certain amount of energy is produced by the descending water in a river which may be slightly altered in its distribution by hydraulic works from one part of the channel to the other, but which on a given length must be invariable in amount for the same discharge, a portion only of this is required for the internal work of the flow of the water, and the surplus must be used up in external work and cannot be got rid of by any other means. However important the ratio of silt carried by a river may be, it is probable that its greatest importance arises from its being an indicator of the external work in operation on the parts of the river concerned; thus showing the distribution of the dynamic head into internal and external work. All the changes the hydraulic engineer can control in the régime of a river are brought about by alterations induced in this distribution. This is true of the basin of reception, of the trunk and of the bed of deposit, where the dynamic head is equally invariable. In the former where the external work is destroying the country it is converted into internal work by barrages across the steeply sloping channels; and in allowing the water to fall in cataracts, when the great commotion uses up the excess work on hard unyielding floors; or, when this can be done, in utilizing it in the direct performance of serviceable work by machinery. In steep rocky mountain streams the excess work is used up in natural cataracts and other commotions, or in re-

Resistance to the flow of a current.

Summary of the writers views.

moving boulders; and in the steep plains the river broadens out of itself and shallows, so as to have the greatest amount of resistance offered to it by the lining. In the navigable trunks of rivers the greater part of the hydraulic operations have been to correct any tendency to undue performance of external work on the banks, and to divert it to the bed. Where the one has been prevented the other has followed as a compensation. This is shown by the results achieved on the Rhine and Garonne. When the operations have been of such a nature as to improve the shape of the channel and to diminish the internal work of the flow of the stream, a greater amount of external work has been brought into play, and other changes have followed in the channel. This necessary law of compensation has sometimes been overlooked in river works. In the delta, or bed of deposit of a river, the dynamic head constantly diminishes on approaching the sea, and the stored up enery MV^2 is utilized both to promote the flow and to continue any processes of excavation and re-deposit of silt which may be in progress there. Gradually this latter alone predominates, especially when the dynamic head ceases to exist; and if the flowing water has not joined an ocean current sufficient to carry the fresh water and the silt away, this latter falls in the immediate neighbourhood. Even when ocean currents take away the river water, it is probable that owing to the cessation of the power of renewing the external work of excavation, the silt falls continuously and is only distributed over a larger delta.

These principles underlie all the explanations to be found in the following pages; and will be further developed in particular cases.

SECTION IV.

The Irrawaddy Delta General.

77. The plains of the Irrawaddy Delta extend from Prome in lat 18°15′ to the sea in lat 15°50′, with an extreme length of somewhat over 200 miles. They are of an irregular triangular shape with a curved base convex to the sea. The sides of the triangle are formed by the Arakan Yoma mountains to the west, and by the Pegu Yoma to the east; the greatest distance apart of these being at the arched base of the triangle whose chord is over 150 miles in length. The general direction of both chains is due north and south, but they converge towards each other to near the latitude of Henzada where their crests are about 80 miles apart, at which distance approximately they continue asunder with a direction slightly west of north to beyond the north of the delta. The Arakan Yoma are probably a continuation of the Himalayas Proper, and are prolonged out at sea in the series of Andaman Islands which out off a huge gulf from the Bay of Bengal. From Cape Negrais, the extreme southern point of the Yomas, the range rises rapidly in height, attaining an elevation of over 2000 feet near Henzada, and above 3000 opposite Prome. Peaks of the chain rise higher than this. The Pegu Yomas have their southern termination at Rangoon, and their northern near Ava. The crest rises slowly to a mean elevation of 1200 feet opposite Henzada and remains about that height in the neighbourhood of the delta. The greater height of the Arakan Yoma brings with it a greater breadth of base; the lower spurs and rolling ground protruding further into the plain on the west than on the east, thus giving a marked characteristic to the outline of the plains.

The delta of the Irrawaddy.

78. The plains themselves are sub-divided into the true and the mixed Irrawaddy bed of deposit by the extreme east and west branches of the river, the Hline and the Nawoon, or, as they are sometimes called, the Rangoon and the Bassein rivers. The former is believed to have been a larger outlet to the Irrawaddy to the north of Prome; and though it has long discontinued to take water from the main river there, it now receives contributions through several small streams and over the left bank to the south of Talokmoh; while two larger branches, the Teindau and the Panlang, are still navigable at high water, taking traffic to the Port of Rangoon. The Nawoon also received a supply of water from the Irrawaddy to the north of Myanoung, but at present its only direct communication with the river lies between the Myanoung and Henzada embankment works, over a few miles of bank, and through the two branches, the Thambyadeing and the Nawoon, the latter of which is open in floods, the former all the year round. Both the Hline and the Nawoon receive independent contributions from torrent streams from the Yomas; and in the altering conditions of the river these may form the principal source of supply. The beds of deposit of these streams have assisted the alluvion of the Irrawaddy in the formation of the mixed plains lying at the base of the hills.

The delta plains. The Hline and Nawoon rivers.

79. A striking contrast exists between the extent of the plain between the Arakan Yoma and the Nawoon; and those between the Hline and the Pegu Yoma. The Nawoon hugs closely the base of the hills throughout

Contrast between the Arakan and the Pegu Yoma.

its lower course; and even in the higher parts rarely has more than 5 or 6 miles of plain land between its channel and the hills. The Hline, on the contrary, everywhere stands out a comparatively great distance from the base of the Pegu Yoma; the width of the intervening plains being sometimes from 20 to 30 miles. These diversified results arise from the differences in the structure of the ranges, the debris from which have been chiefly instrumental in forming the plains. In both ranges the declivity of the slopes is very steep; and the rainfall similar in amount, though probably the western Pegu Yoma receives a somewhat heavier supply than the eastern side of the Arakan Yoma. But this latter range is composed of harder rocks, which do not yield readily under the action of the rainfall. The more exposed layers are of earlier tertiary formations, and consist of clayey schists and shales, and harder sandstones. The Pegu Yoma is wholly of the latter tertiary, with softer clays and more friable sandstones. The process of excavation is more rapid in the reception basins of the torrent streams on this side; and the ratio of silt brought down much greater than with those of the western range. This is the case now; and the hydraulic state of this Sub-Yoma plain has long called for serious consideration. It presents problems, which have given rise to controversies, and a general examination of the conditions of these questions will find place in this report. Connected with these are the proposals for the irrigation of the northern parts of the plain, which must also be adverted to.

The Pegu Sub-Yoma plain and Yoma torrents.

80. The mixed plain formed by the conjoined deposits from the Irrawaddy water, and from the Arakan Hill torrents extends to the north of the present Nawoon entrance, as far as Kyangheen. One important hill-stream, the Patashin, enters the Irrawaddy between Kyangheen and Myanoung, almost on the spot where the older opening to the Nawoon was, and must have contributed by its deposits to the formation of the plain land near its mouth. A part of this to the north of the stream, some 6 square miles in extent, has been embanked from the river floods. This work is called the Kyangheen embankment. To the south of the Patashin the plain extends along the right bank of the Irrawaddy some 40 miles to the Nawoon entrance with an average width of ten to twelve miles. Two torrent streams the Ma-mya and the Ok-pho enter the plains from the Arakan Yoma within this distance. They bring down only moderate quantities of silt; but as they enter the low plain in the part behind the Myanoung embankment they offer grave obstacles to the complete success of the reclamation of this plain attempted by that work. This embankment skirts the southern edge of the Patashin, and keeping close to the bank of the Irrawaddy has at present a continuous length of 44 miles; its length having originally been intended to be over 54 miles. It was to have extended across the openings to the Nawoon river. Portions of this intermediate work have been executed; and from time to time projects have been brought forward to complete the work, either by closing entirely the branches from the Irrawaddy to the Nawoon; or, leaving this open, by carrying the embankment a sufficient distance down the Nawoon river, and diverting also the exit for the Ma-mya and Ok-pho streams. In either case the thorough amelioration of this important plain must include a complete and sufficient method of dealing with these torrents. Up to the present time, and probably for sometime yet, changes still occurring on the Irrawaddy river in this neighbourhood render impossible or extremely difficult any suitable solution of the difficulties. When these changes cease the whole question will be much simplified. As the projects of different engineers for dealing with this have been proposed in some detail they can only be done justice to by treating them with detail. The consideration of these and other difficulties attending this Myanoung embankment work will therefore be reserved to the final part of this report. The general aims and results achieved will be considered in the present part.

The Arakan Sub-Yoma plains.

The Kyangheen plain.

The Myanoung plain.

The Ma-mya and Okpho torrents.

81. The condition of the lower part of the Arakan Sub-Yoma plain is bound up with that of the embankment on the left side of the Nawoon river, which forms one branch of the great Henzada embankment work. Unfortunately this plain is not likely to share in the prosperity now ensuing, and still progressing, which that work brings to the Irrawaddy plain protected by it. The construction of this embanknent has been a complete success financially; and the breaches due to the high floods of 1877 have rather demonstrated its value as a protective work by the small resulting damage than shown its inefficiency. The plain reclaimed by it is pure Irrawaddy alluvion, undisturbed by torrent streams and their deposits. It lies to the right of the main channel of the Irrawaddy, and between it and the Nawoon. The part so far protected is triangular in shape, resembling in proportion and outline the main part of the delta. The work was originally intended to be a single embankment line continuous with the Myanoung one; which, after crossing the closed branches to the Nawoon, was to terminate at Pantanaw. The suspension of the closing operations brought with it a change in the design. The work was commenced at the vertex of the triangle, and carried down both the Irrawaddy and Nawoon rivers simultaneously. It has now reached 53 miles on the Irrawaddy side, and a project has been submitted to extend it to Pantanaw during the present year (1879.) A still further eventual extension is under consideration, from Pantanaw to Shoayloung, which will change the form of the protected plains to an irregular parallelogram, to the mouth of the Daga river. On the Nawoon side the work has been executed for over 70 miles, and a proposed extension now ready for submission will carry it to over 99 miles to the mouth of the Daga river. The enclosed plain will then be about 58 miles long by 36 wide or somewhat over 2000 square miles in area of rich alluvial plain, admirably situated within easy reach of two great sea-ports, and on the line of a large inland traffic. It is intersected with navigable channels of clear water, while no part of its area is more than 20 miles in a straight line from either the Nawoon or the Irrawaddy. Its rainfall is so abundant that a much smaller supply than usual, such as occurred in 1878, is attended with no ill effects. No engineering difficulty of any magnitude has attended, or is likely to result from the construction of the Irrawaddy branch of the work. Some retirements of the line of work have had to be made owing to changes in the course of the river, and one is now (1879) in progress. Several large streams running from the Irrawaddy to the interior of the plain have been dammed across and the embankment has been carried over the dams. In a few cases slips of these dams have occurred, but were met by timely precautions. The extension to Pantanaw raises no difficulties whatever. It terminates on a large stream called the Baudee, which serves at once for the navigation and for the drainage of the interior plain. The further extension to Shoayloung will raise the question, can the requirements of this navigation and drainage be adequately provided for if the Baudee is permanently closed, or must special means be devised to meet them? Only general considerations will be at present entered into in discussing these questions; all special ones being reserved for future submission with the fully detailed plans.

The lower Arakan Sub-Yoma plain and the Henzada embankment.

The Henzada plain.

82. The Nawoon branch of this embankment has accosted the difficult problem of entirely shutting in the overflow of that river to its natural channel. Some failures occurred in the progress of the work, partly arising from the unprecedented nature of the floods of 1876 and 1877 on that side, partly from the insufficient strength given to the works at first. The economic results have been favorable; for while, on the one side, a portion of the Arakan Sub-Yoma plain has been submerged to an additional depth of about 3 feet by the permanent raising of the river surface, the loss of agricultural ground has been small; and, on the other side, a magnificient plain has been entirely redeemed from annual inundation with a consequent immense spread of cultiva-

The Nawoon river embankments.

tion. The Engineering results may now be claimed as a complete success, with only remote possibilities of further failure through still greater floods than have occurred in this part, or through unforeseen causes. As the further progress of the works is contingent on this being clearly demonstrated, and detailed statements of somewhat elaborate observations and measurements are necessary for that purpose, these are reserved for the final part of the report. The project for continuing and completing the work to the mouth of the Daga river is now ready, and as this also raises questions regarding the navigation and drainage of the Henzada plain, it will be convenient to discuss these also in detail, with the record of the past progress of work, merely giving the general outlines at present.

The Hline Valley plains.

83. The lower part of the plain between the Pegu Yomas and the Hline River, and all the plain on the left bank of the Irrawaddy from the south of Talokmoh to Yandoon is subject to annual inundation. The principal cause of this is the overflow from the Irrawaddy above the banks and through the creeks already referred to. The great mass of water thus thrown in is met by the flood discharges of the torrent streams from the Pegu Yoma; and the combined floods spread over the whole of the low ground, as the Hline river channel is quite incapable of carrying them off at once. The depth and spread of the water vary from year to year, and there is a wide margin on the eastern side between the limits of inundation of ordinary floods, when the water does not rise above 37 feet on the Myanoung gauge, and those of the years 1871, 1875 and 1877. The limits of the latter flood have been marked on the map of the Delta with hatching (Plate VII.) These are fairly accurate in the upper part and as far south as Thongzai, but south of that they are only approximate. The ground inundated in ordinary years is permanently unfit for cultivation. This is about 100 miles in length and averaging from 10 to 12 in width. Half as much again has only a precarious cultivation, having been submerged four times in the 10 years 1868 to 1877. The inundation of this part also exercises an injurious effect on the floods of the torrents, as they are prevented from coursing freely to the Hline, and often spread over the country, both their water and their deposits. It has been designed to remedy the greater part of these evils by a single embankment from Talokmoh to Yandoon, called the Tharrawaddy embankment from the name of the District through which it passes, which shall entirely cut off the Irrawaddy water from this portion of the Hline Valley. A general description of this work and the problems raised by it with the proposed methods of solution will find place in this part of the report; while their final discussion must be reserved for a separate one.

Tharrawaddy Embankment.

The Irrawaddy River between Saiktha and Yandoon.

84. The portion of the trunk of the main river lying between Saiktha and Yandoon is intimately connected in all its varying conditions with the embankment works, whether as it may affect those actually existing and the proposed ones, by the changes now naturally in progress upon it, or in the probable results to be artificially brought about by the complete construction of the works designed. The materials for a study of this part of the channel are tolerably complete, and a concise account of these under the former aspect can now be given, while the latter will more naturally be dealt with in the detailed discussion of the Tharrawaddy embankment. The present report will thus give a description of the principal features of this part of the channel, and the changes naturally occurring upon it, with their results; and will notice more or less critically the various proposals for dealing with it.

Enumeration of Sub-division of the subjects.

85. The different plains now enumerated make up the whole of the upper delta of the Irrawaddy; and the hydraulic works affecting them, hereafter to be considered, may be thus recapitulated.

(a.)—The Pegu Sub-Yoma Plain.

1st.—The regulation of the torrent streams from the Pegu Yoma.

2nd.—The irrigation of the northern parts of this plain.

(b.)—The Aracan Upper Sub-Yoma plain.

3rd.—The Kyangheen embankment.

4th.—The existing Myanoung embankment.

5th.—The projected works for completing the Myanonng embankment.

6th.—The regulation of the torrent streams Ma-Mya and Ok-pho, and the drainage and other ameliorations of the Myanoung plain

(c.)—The Henzada plain.

7th.—The Henzada embankment, Irrawaddy Branch.

8th.—The Henzada embankment, Nawoon Branch.

9th.—The interior navigation and drainage of the Henzada plain.

10th.—*(d.)*—The Aracan lower Sub-Yoma plain.

(e.)—The Hline Valley.

11th.—The Hline river and the inundated plains.

12th.—The Tharrawaddy embankment.

(f.)—The Irrawaddy river in the upper delta.

13th.—The features of the river and the changes now naturally occuring in it.

The writer has had to take up, in his professional capacity during the last fifteen years, each of the subjects covered by the above heads, in order to report upon it. In some cases this has only been done casually and without the full study which such matters require. In others they have formed and still form the principal works under his charge, where action has had to be taken, or still is pending. On these points frequent reports have been made, and numerous surveys and observations embodying the fullest details have been executed. Frequently, opposing views have been held by different authorities; and, though the course actually pursued in carrying out the works has received the sanction of the Government, it cannot be denied that different courses were open, and sustained by practical Engineers who are entitled to the highest deference. In most instances the questions have been decided on the grounds of expediency and suitability at the present time; in a few, radically different plans have been proposed. In the general account of the whole to be shortly given the nature of the researches carried out will be indicated, in order that the degree of confidence in the proposals made may be measured, and such illustrations added from other sources, as will make up for the want of extended experience upon this river and its works. The principal facts available will be given in such a manner that independent opinion may be come to on the points at issue; and the more important ones treated at greater length and with fuller detail.

The lower delta of the Irrawaddy.

86. The lower part of the delta has so far raised no questions of great practical importance in a hydraulic point of view, though various proposals have been made regarding it, which at present of merely speculative interest, may ultimately prove worthy of closer attention. These can only be now noticed in the most general manner, and will be disposed of so far as this present report is concerned, with the following description of the remainder of the delta.

Sub-divisions of the delta.

87. The whole delta of the Irrawaddy can be considered as divided into three parts, each possessing characters widely differing from the rest. The one whose component parts have just been considered is the upper delta, which has in a measure ceased to be, and will before long wholly have ceased to be the bed of deposit for the alluvion of the river.

The Upper Delta.

South of it is the lower or marine delta including all the region between the upper delta and the sea coast. This is still the recipient of a great part of the alluvion, and the river is actively engaged in consolidating and extending its conquest from the ocean here. Beyond it is the sub-marine delta, which receives the balance of the alluvion brought down by the river. The first difference observable between the upper and lower delta is in the extreme sub-division of the latter by several great branches of the river flowing direct to the sea, and the innumerable minor streams crossing from one branch to another. There is no such unity in its parts, and no such extensive plains to be found here without sub-division as in the upper delta. Apparently, from the map, the higher region seems as much sub-divided, relatively to its extent, as the lower ; but the numerous streams have long been abandoned by the river as active branches except at high floods, and are now only useful for navigation and interior drainage. The river has, of itself, been slowly closing all the upper branches through which it formerly discharged. It has successively closed that above Prome, the one near Myanoung, and that of the Nawoon, which only re-opened within the last 20 years. It is fast closing the Teindau ; and even threatens to close the Panlang at Yandoon. The numerous smaller exits have been long in slow course of silting up, and the complete exclusion of the river from all its outlets north of Yandoon by artificial works will be but following out the course pointed to by nature. This would transfer the future head of the delta to the neighbourhood of Yandoon and Pantanaw ; and even if the Nawoon continues open, it will be an insignificant branch compared with the main river.

The lower or Marine Delta.

The Sub-marine Delta.

88. A more marked difference consists in the degree in which the various branches and streams are affected by the tide. This is slightly felt in the main channel, in the dry weather, as far north as Mengyee, but only as a check to the flow of the river with a scarcely perceptible rise and fall. From Donabyo to Yandoon a slight flow backwards is sometimes felt ; and becomes more marked on proceeding southwards. On the lateral rivers, the Hline and Nawoon, the tidal influence extends higher. At Sanyuay on the former river there is a rise and fall in the dry weather of 3 feet, with a distinct flow ; and at Nga-thain-gyoung on the Nawoon the rise and fall is $2\frac{1}{4}$ feet. In high floods no such influence is perceptible in the upper delta, while it continues throughout the year in the lower, forming thus its most distinctive feature. The line of demarcation between the two cannot always be traced ; though the contrast is strongly manifest in the extreme parts. There is, however, one strong resemblance between the streams of the upper and lower delta. As a rule their banks are higher than the neighbouring ground. Numerous levels have been taken in the upper part ; and will be referred to. The most noticeable is one at the bottom of Plate VII ; extending from the Aracan Yoma near Nga-thain-gyoung to the Pegu Yoma beyond Thongzai. It crossed the Arakan Sub-Yoma Plain, the Nawoon river, the Henzada plain and Daga and Irrawaddy rivers, the Hline valley and Pegu Sub-Yoma plain, and gives a clear profile of the surface of the country. Almost all the streams except the Hline river show that remarkable feature. It is the same with every water course in the lower delta. The banks of the creeks are the highest part of the ground. The intervals between the creeks are shallow basins into which the water flows at high tide, and where silt is continually deposited.

Difference between Upper and Lower Delta. The tidal flow.

89. A more important difference, the one on which the others depend, is due to the greater fall of the land in the upper delta than in the lower. Levels have been taken along the banks of the Nawoon and Irrawaddy rivers in the upper delta and connected with mean sea level. There is some doubt as to the correctness of the datum for this level ; one which was brought by Colonel Stoddard from Prome to Myanoung from the railway levels carried

Fall of ground in upper and lower deltas.

from mean sea level at Rangoon being 4·54 feet lower than another furnished at the same place by the Grand Trigonometrical Survey, brought by angular readings from India. The levels on the embankment works have been connected with the former. The high flood marks of 1875 at Saiktha, 230 miles from the sea by the nearest channel is about 77·93 feet above mean sea level. Donabyoo 130 miles lower down has the same flood mark only 24·46 feet above the mean sea level. The fall is thus at high flood 53½ feet in 130 miles or 0·412 feet per mile. The low water level at Donabyoo in 1875 was between 1 and 2 feet above mean sea level. A similar flood slope continues for some distance lower down, though it gradually lessens. The fall of the 1875 flood surface from Donabyoo to Pantanaw is about 13 feet which thus leaves only 11½ feet of fall for the flood water surface in over 70 miles by the nearest channel. It will be observed on the map that if the Nawoon branch to Bassein, and the Yandoon branch to Rangoon, which as a discharging channel is of equally small importance in its effects on the main river with the Nawoon, be neglected, the whole of the principal branches of the river diverge from the neighbourhood of Pantanaw, and spread nearly over the whole face of the delta. The configuration of the channels shows of itself that the true bed of deposit here has of later times been much restricted in area, and lies within the confines of the spread of the waters brought down by these channels, which is estimated at 9-10ths of the total discharge of the Irrawaddy.

The Irrawaddy bed of deposit.

90. The point of divergence of the more active branches of the Irrawaddy near Pantanaw corresponds with the exit gully of a torrent stream, in its situation at the highest part of the conoid of deposit which radiates from there. This conoid is approximately defined by the two branches—the Yuay river on the west, and the China Buckeer on the east; which, without extending to the Nawoon and Hline branches, are immediately neighbouring to them. Probably the high rolling ground marked as hills in both intervals has had much effect in limiting the spread of the conoid of deposit. which would otherwise have reached to the Bassein and Rangoon rivers. The distinction now pointed out in the condition of parts of the marine delta is not immediately apparent to an observer passing through that region, but a closer examination confirms it as valid. The whole of the tract to the west of the Yuay river is deprived of its proportionate share of silt. This branch itself has only a slight connection with the more central branches and the quantity of silt-laden water brought to that land from this source is small. In the highest floods of the Irrawaddy the Nawoon does not drain off more than from 100,000 to 120,000 cubic feet per second of water, where the main channel carries from 1,400,000 to 2,000,000; and some portion of the silt in this is lost on its course southwards. A much greater extent of this region is elevated far above water mark than that shown as hilly land on the map. It is probable that this elevation is due to subterraneous causes; and it is certain that the whole continuation of the immense plain or series of plains whose northern parts are protected by the Henzada embankment is very little liable to be actively affected by the operations of the main river, and has thus acquired a state of stability rendering it easily available for artificial ameliorations. No works of any kind have been hitherto proposed for this part, much of which, from its elevation, is probably not of great value for rice cultivation at present.

The Yuay river and plain west of it.

The Nawoon or Bassein river.

91. The Nawoon or Bassein river has two mouths. From Bassein, or from the mouth of the Daga southwards, it is rather an estuary of the sea than an ordinary river. It is accessible at all seasons for sea going vessels of the largest tonnage. The least depth known on the outer bar is about 24 feet. The channel is wide and very deep. In the SW. monsoon sailing ships can carry sail all the way to the port, which is ninety miles from the sea. There are no shoals or dangerous parts in the whole of this channel, which thus forms one of the finest

natural harbours in the world. An attempt was once made to found a new sea port at its mouth, called Port Dalhousie, and Hengy Island just outside was occupied by an English factory in former times; but this part of the coast is unhealthy, and Dalhousie lay in the path of cyclones. The neighbourhood is now abandoned. The ridge forming the Alguada and Andaman Islands was formerly a source of great danger to passing vessels; but now, thanks to the lighthouse system devised and executed by Colonel Fraser, the approach to the coast has been made perfectly safe; and a telegraph connection to Diamond Island makes that a convenient place of call for orders for ships.

92. On the Rangoon side, the tract lying between the China Buckeer and the Rangoon river is also removed from the more energetic depositing action of the Irrawaddy. It is also less intersected by creeks than any other part of the marine delta. The Panlang Creek forms the southern boundary of the plain to be protected by the Tharrawaddy embankment; and it is also the northern boundary of the great Twantay plain, the tract referred to. This creek forms the short cut at high water for steamers from Rangoon to the Irrawaddy. It is closed to all but the smallest boats in the dry weather by deposits of silt at its head. One of the most urgent requirements of navigation, which has been pressing since the British occupation, is to keep open this channel all the year round. This subject will be presently considered. No other creek of magnitude crosses this plain until its southern limit, when what is called the Bassein Creek runs from the Rangoon river, at about 12 miles from the sea, to the China Buckeer near its mouth. This forms the steamer dry weather channel from Rangoon to the Irrawaddy. Formerly there was a comparatively large creek open from Dallah, opposite Rangoon, to Twantay; but this now remains closed, except for boats at high flood, although proposals have been made to re-open it. The greater part of the land in this neighbourhood is eminently suited for rice cultivation; and if protected from inundation, would at once be taken up; its position near Rangoon, and its great fertility rendering it one of the most desirable districts in the Province. A careful examination would determine whether such protection should take the form of one large encircling embankment, or of several smaller ones. If the minor creeks could be closed with safety the former is to be preferred, both from motives of economy, and from its permitting a general scheme for drainage to be carried out.

The Twantay plains.

93. The mere embanking of this plain, and of the Bassein and other plains of the marine delta can be carried out with ease and economy. No engineering difficulties of any kind can be raised by such works. Every creek marked on the map, and every large branch of the river offers in its raised banks natural embankments almost level with the high flood water, on which artificial works of moderate dimensions can be raised. The closing of the creeks, even of the larger ones, does not offer grave difficulties. The water does not rise much in highest flood above ordinary flood, and no extra raising of surface would be caused by the works. The banks rarely excavate, and only in a small degree when they actually do so; owing to the deficient dynamic head to the flowing water resulting from the diminished slope in the marine delta. But this loss of slope introduces a new difficulty. The natural drainage of all the plains of the upper delta is carried off by the old channels, which are left open at their lower ends, and are much larger than will suffice for any requirements. Much loss of excellent land is caused by leaving them open, as the flood water rises and finds its way some distance inward, but owing to the fall of the ground the lower land thus lost is small, relatively to that saved in the higher part. The difficulty thus experienced in the upper delta, and it is a serious one, is intensified in the lower. In the higher floods the water would stand almost as high inside the embankment as outside, if any openings were left; and were the whole encircled with embankments, which is the

Facility offered for embanking Lower Delta.

Difficulties of draining land in lower delta.

only course possible to keep the river water out, expensive machinery and skilled labour must be employed to pump out the water gathered by percolation or from rainfall. It is doubtful whether the country is sufficiently advanced to justify resort to such means on a large scale at present; and it does not fall within the scope of the present report to enquire into the question. But it is a fact, upon which too much stress cannot be laid, that the exceedingly easy terms on which the Henzada plain has been embanked, and which to some extent are still open, will not be renewed in any other part of the delta. The great value of the prize now in hand has been systematically underestimated and overlooked, and will only be made manifest when the terms on which alone success is possible are demanded for the future work to be done. The reclamation of the Tharrawaddy plain is attended with onerous conditions which have to be well weighed. That of the marine delta plains will require an expenditure of money and a continuous care vastly greater than any yet called for on the Irrawaddy. But the success of such works in Holland and Belgium and on the Ferrara plains of the Po, where enormous sums of money have been expended, justify consideration being given to the future reclamation of these plains of the Irrawaddy delta, which are perhaps the richest in the whole world.

The Rangoon River.

94. The Rangoon river, like the Bassein river, has only a casual connection with the Irrawaddy; and between Rangoon and the sea it is a true marine estuary. Fortunately for the interests of the Province, although there are grave obstacles to safe navigation, there are none which cannot be overcome by careful Pilotage on the entrace to this magnificent harbour. It receives above Rangoon the Panlang branch of the Irrawaddy, and the Hline river with its numerous contributaries; while just below Rangoon the Pegu river and Pazoondoung creek enter with drainage from a portion of the eastern slopes of the Pegu Yoma. All these are silt bearing streams, and, though the dynamic head when they arrive at Rangoon is very much diminished, there is still an excavating power in the water which is threatening some of the banks in the neighbourhood. A large deposit of alluvion occurs opposite the junction of the Pegu and Pazoondoung rivers with the larger stream near Rangoon, which is called the Hastings shoal. Mr. Leonard, Civil Engineer, examined and reported on this and proposed a system of piers to direct the currents on to the shoal. The work would have been extremely expensive, and, so far, it has been found possible to avoid the evil in a measure, without taking any steps to remedy it. From the shoal to the mouth no difficulty arises, but the sea entrance is liable to difficulties from the channels and bars changing. The changes are carefully surveyed and recorded from time to time, and the difficulties are overcome by careful navigation. It is not probable that any engineering works can permanently improve the existing condition of things there.

Tributaries of Rangoon river.

Other branches of the Irrawaddy.

95. On examining the other branches of the Irrawaddy it will be found that though it has several mouths, these open from only five principal branches connected with the main river. The five taken from west to east are:—the Yuay river, the Pyama-lau river, the Irawadi or E-rá-wá-di (ဧရာဝတီ), the name being given to the Pantanaw branch by the Burmese (1), though the next two, the Dallah and the China Buckeer, are the most important arms at present. All the five channels are deep and navigable for large ships within the coast line; but little is known of the state of their bars or entrances, which must be very variable, owing to the large quantities of alluvion brought down by the water, which there meets the sea currents and has entirely lost its dynamic head of flow. Little also is known of the lower part of this immense network of creeks and swampy lands. It is only within the last few years that an accurate survey has been made of the coast; and though it is known that

(1).—Or rather to a large arm opening below Pantanau; where traces of the old main channel are still to be found. The Pantanau branch is small at its opening.

accretions of alluvion continually take place outside the various mouths, no measurements of the rate of progress made are available to record the extension of the Delta. The reticulation of lines on the map conveys but a faint idea of the actual sub-division of the land by the innumerable minor creeks crossing between the larger streams. One sub-division of the Bassein district here is known to the natives by the name of "the fifteen hundred creeks;" and other parts are equally cut up by tidal streams. There is a continual circulation of water through them with the rise and fall of the tide which favors much the distribution and deposition of the silt, and thus they facilitate the extension and consolidation of the land.

Reticulation of creeks in the Marine Delta.

96. In this they are principally aided by the characteristic vegetation of the Marine Delta. The late Mr. Sulpice Kurz, who examined the forests of Pegu, thus describes this vegetation:—(1) "The littoral forests stretch all along the coasts, wherever flat shores and alluvial deposits prevail. They extend as far into the interior (especially in the so-called deltas of larger rivers) as the tidal wave penetrates. In Pegu itself the tidal zone in a line drawn from Thayasoo to Bassein will probably indicate the general limit of the littoral forests. They do not, however, cover the whole extent of the country (as is the case in the Soonderbuns of lower Bengal) south of this line, but are restricted to the alluvial formations, and more especially to the immediate vicinity of the rivers and tidal channels. They are often enough interrupted by other kinds of forests, which either grow on the higher grounds or on diluvial formations. Neither are they uniformly composed of the same trees, but vary as much in their constituents as do all other forests in Burma. For this reason I found it useful to divide them into the two following varieties, *viz.*

Vegetation of the Marine Delta.

(*a.*)—Mangrove jungles and swamps, covered regularly by all tides.

(*b.*)—Tidal jungles, usually covered only during spring and higher tides.

"(*a*).—Mangrove jungles. These forests in the sense I take them occupy the flat muddy shores along the sea, and especially along the estuaries of rivers and streams, forming the outer skirt of vegetation, and often extending (during flood tide) far into the sea. They are regularly submerged by the tides, and are very poor in species, when compared with other forests. They form rather dense and usually low jungles of 40 to 70 feet in height with dark green foliage. The most characteristic trees and shrubs found here are those which are generally known under the name of mangroves, such as Bruguiera gymnorhiza, and sometimes B. oxyphylla, Rhizophora conjugata and Rh. mucronata (all these called by the Burmans pyoo) further Ceriops Roxburghiana, Kandelia Rheedei, Sonneratia apetala, S. arida and S Griffithii, Lumnitzera racemosa, carapa obovata, Scyphiphora caryophyllacea, Brownlowia lanceolata, Aegiceras corniculata, Acanthus ilicifolius. Amongst the poor shrubbery Acanthus volubiles, a Hoya Acrestchium aureum, and a few others are found.

Mangrove Jungles.

"Where Bruguiera and Rhizophora prevail, the soil is washed out from the roots by the sea in all directions, so as to form often a complete labyrinth of network, presenting an ugly and dirty aspect. Numerous irregular short stems of undeveloped trees, looking like pinnacles or irregular knobs arising from the exposed roots accompanied by numerous mangroves in all stages of growth from the stick-like seedling up to the full-grown tree, make walking amongst them very troublesome. The grey mud which is so soft that one sinks continually up to above the ankles, bears hardly any other plants, except seedlings of such families as are of a mangrove character. The ground burrowed by various sea animals such as crabs &c., is submerged during flood tide, when the lower trees and shrubs show only their crowns above the sea, while the higher mangrove trees, sticking out from the expanse of water

(1.)—Kurz S.—Preliminary Report on the Forest and other vegetation of Pegu 1875 p. p. 28 & 29.

appear like a floating forest. These are usually the trees of which we first catch sight when approaching the shores of a low country.

"*(b.)*—Tidal jungle. The tidal jungles resemble in many respects the mangrove jungles, especially along the very borders of the tidal channels, but they are usually devoid or nearly so of true mangroves, such as Bruguiera, Rhizophora, &c., They not only occupy the sea-shore, but far up country, especially along the various river systems. They are even found where the influence of the tide is very considerable and the water only very slightly brackish. Their average height is from 40 to 50 feet, or even in some cases higher, and sometimes they are reduced to shrubs. They have plenty of shrubby undergrowth. During spring tides they are more or less inundated, but ordinary tides seldom reach them. The most characteristic trees here are Sonneratia apetala and Aviennia tomentosa, forming nearly one-third of their entire bulk. According as the one or the other of these two trees prevail, we see these forests assuming a rather willow-like appearance with drooping branches and lace linear foliage of a light greyish green color; or low jungles present themselves of a mean height hardly exceeding 25 to 40 feet with a broad dull green foliage collected into dense almost spherical crowns."

Tidal jungles.

97. While no exception can be taken to this description of the vegetation the writer thinks that Mr. Kurz has mis-understood the functions and the relative action of the water and the roots of the exposed vegetation. Several years observation of the tidal creeks tends to prove that the roots of the mangrove and other littoral plants project of themselves into the water to derive nourishment from the thick coating of silt they are invariably clothed with. The borders of all the lesser creeks, where no excavation of the sides is going on, or is possible, are lined for many feet thickness with impenetrable masses of dense foliage, strong lithe branches and pendulous roots dipping into the water. These are found in an inextricable confusion of all sizes from the finest thread to the strongest trunk, and appear to grow in thickness or by absorption into each other. They form a screen which most effectually separates a large portion of the silt from the water and causes the precipitation of a large quantity of the softer alluvion. They especially predominate in the creeks where the tidal flow is the feeblest; and to their action must be ascribed the gradual closing up of many of the minor channels crossing from one branch to another. In the principal branches, especially in the upper parts where the strongest rush of water takes place, this action is lessened. The process described accounts for the present condition of the country and tidal creeks.

Function of the vegetation in the marine delta.

98. It is with great difficulty that large steamers pass from Rangoon to Bassein. The traffic is at present conducted by small twin screw steamers of about 100 tons which pass from the China Buckeer branch to the Pya-ma-lau by the northern junction, and then find grave obstacles to crossing to the Bassein river. The only available channel is a sinuous stream called the Pooloo, which presents a serious obstacle to any increase in the size of the vessels used. It has been improved under the writers direction by cutting away the overhanging branches of trees, and removing the projecting stems and roots; but the only possible method of permanently improving the navigation so as to permit large steamers to pass appears to be the cutting of a straight canal of 4 or 5 miles in length between the Pya-ma-lau and the Yuay river. Such a canal 80 feet wide at top, 64 at bottom and 8 feet deep would enable steamers of 400 or 500 tons to pass the whole way from Rangoon to Bassein at all seasons. Its cost per mile would be 30,000 Rs. If this joined the western entrance of the Pooloo to Yuathagyee village, the nearest point of the Pya-ma-lau, the length would be 4½ miles, and the total cost 1,50,000 Rs. A further cut of 1½ miles from Gan-

Navigation Rangoon to Bassein.

Canal proposed to improve the communication.

thoo-thoung to Thayagong, would at an additional cost of 45,000 Rs. lessen the distance traversed by the steamers by from 20 to 30 miles with great advantage to all concerned.

Silt brought down to marine delta and to sub-marine delta.

99. The total quantity of silt brought down by the river has been calculated (vide ante Tables 16, 17, 18) at 291,429,000 tons annually, or sufficient to cover 150 square miles one yard thick. A somewhat arbitrary division has been made of this amount into 115,163,871 tons utilized in the main delta, and 176,381,171 tons conveyed away by the water to the submarine delta, the division being founded on the assumption that most of the heavier silt remained behind. An allowance should be also made for the alluvion rolled down along the bottom. Although a compensating process takes place in the trunk of the river by which all the material excavated is laid down in other parts of the stream, this re-deposit always takes place lower down and there is a continual progress sea-wards of the whole. The rate of this progress is unknown, and the quantities of matter moved are unkown; but probably have some fixed relation to the silt carried. It is sufficient at present to indicate the fact without precising any figures. If for the sake of fixing the ideas we take the quantity to be half that of the silt, we have sufficient earth to cover 75 square miles one yard thick. Taking one half the total to be left in the marine delta, the area of the portion of this, when the greatest activity of deposition is displayed, is about 3,500 square miles in extent. The annual raising of the surface, if the silt were laid evenly over this, would be at the rate of $\frac{3}{4}$ of an inch, which would produce very perceptible results in a few years; and if the extension of reclamation works excludes a larger area from the bed of deposit the result must be either to increase rapidly the raising of the remaining area, or to extend it by protrusion into the region of the submarine delta.

The Sub-Marine Delta of the Irrawaddy.

100. The position and extent of this is very little known, many years ago Captain Heckford published a chart of the Burmese gulf cut off by the Andamans from the Bay of Bengal. A reproduction of this is taken from the chart given with Colonel Fraser's Light-house report. Very few additions have been made to our knowledge of this part of late years, but a survey is now in progress by Captain Jarrad R. N. which will ensure accurate results. The configuration of the various deltas at the head of this gulf is noteworthy.

The deltas of the Irrawaddy, Sittang and Salween.

Three rivers debouch into it at this part, the Irrawaddy, the Sittang and the Salween. That of the Salween is scarcely noticeable, notwithstanding that the river is one of the longest in the world, with a large discharge of probably over 600,000 cubic feet per second in flood; and through all its lower course has a great surface fall, broken by cataracts. The mountains through which it passes must be of hard unyielding rock to offer such small results in the bed of deposit. The Sittang which is a small and comparatively unimportant river appears to be rapidly making land in its delta. It receives tributaries from the Pegu Yoma which bring large masses of excavated earth down. The funnel-like shape of its estuary and that of its bed of deposit resemble somewhat those of the Irrawaddy, as it must have been at an early stage. There is a gradual process of shoaling up apparent on the fore shore which must finally emerge as dry land. At present a tremendous bore rushes up the estuary, rendering the navigation in the neighbourhood dangerous. It is felt many miles up the channel of the river. Shoal water extends far out in front of the Irrawaddy delta in the Baragon Flat and Krishna shoal. It is possible that the heavest portion of the alluvion, the sand and gravel rolled along the bottom, finally reaches those shoals, but they present no hard substance to the bottom of vessels which occasionally ground upon them. Nor are they quicksandy. A vessel running aground at low water has only to wait for the rising tide to move without inconvenience. In less than the space of one degree south, the water deepens to over 36 fathoms;

but Captain Dundas Taylor, Hydrographer to the Government of India, states that a french vessel found shoal water at about this distance directly in front of the central Irrawaddy branches. As already explained the Dallah and China Buckeer rivers bring down at present the larger share of the discharge and silt of the river. If, as is possible, this has long been the case, some reason must be offered for the smaller protrusion of the delta there. This can perhaps be found in the ocean currents of the Bay.

Ocean currents in front of the Irrawaddy Delta.

101. Captain Heathcote I. N. describes the currents of the Bay of Bengal in the south west Monsoon (1). He shows that a current sets north-easterly towards the Arakan coast and sweeps up the Bay on that side. What may be a branch of this, commences about lat 180°8′ and long 90°, and running at the rate of $\frac{3}{4}$ to $1\frac{3}{4}$ miles per hour in a south easterly direction towards Preparis Island and passing through the deep channels there, turns easterly towards the Gulf of Martaban. Captain Heathcote says "from its eastern edge the currents turn off to the north eastward until near the coast of Pegu, they become governed by the form of the land and take a course to the north-northwestward, joining those on the coast of Arakan already described." This must induce a rotatory movement in the currents in the north west of the Gulf of Martaban, where the flow strikes directly against the land. It is known that such currents exist there, and with strong excavatory action. The Krishna Light-house, shown on Colonel Fraser's chart, was a building on iron piles fixed in the shoal near the mouth of the China Buckeer in 2 fathoms of water. The whole of the shoal in front of it was swept away with the building itself in 1877 and subsequent soundings gave 5 fathoms on its former site. A continued repetition of this process would result in giving the hollow form of front now apparent in that neighbourhood, notwithstanding the continual deposition of the largest quantity of the Irrawaddy alluvion in that part. The final results would be a re-distribution of the silt over a wider area, not, however, very distant from the first place. Ocean currents can have no carrying power of silt in themselves. It is only on shallow shores by a process of continual excavation and re-stiring up of deposit that they can transport it. Silt would fall in the strongest deep current towards the bottom in just the same time in which it would in standing water; the only difference in the result being a distribution of the quantity over a wider area.

Remaining plain of the delta.

102. The only other points calling for attention regarding the marine delta are the navigation channels from Rangoon to the Irrawaddy, and some proposals which have been made regarding the reclamation of land in the neighbourhood of the new district town of Ma-oo-bin. The land on which this stands is one of the shallow basins peculiar to the delta with edges even with high flood, and low interior lands capable of yielding a rich return. The whole of the high borders of the creeks in the lower delta are utilized or being rapidly taken

Since the above was written, the following extract from a letter dated 28th March 1863, of Captain Fitzroy, R. E., Superintendent of the Pegu Survey to the Chief Commissioner, was met with which specially refer to these tracts.

"Within the jurisdiction of the townships of Phya-pon, Eng-tay and Thonkwa, and bounded by the Dallah or Kyon-ton or Eng-tay on the west, and by the China Buckeer or To river on the east will be found some 2,000 or 3,000 square miles of land whose rich alluvial plains now rendered desolate by the annual inundation of the waters of the Irrawaddy, seem to me to demand the first and most prominent consideration in any report connected with the embankments of this province."

"And it is to this portion of the Delta that I would respectfully direct the particular attention of the Chief Commissioner."

"There are doubtless other and numerous minor tracts that would be benefited by a general system of embankments which perhaps I may hereafter be able to specify in a detailed report."

"But I am of opinion that there are no other tracts within the precincts of the delta, that can equal in importance, rival in magnitude, or offer such facilities for redemption, as those which are here alluded to."

(1.)—Heathcote Captain J. A., R. N. Surface currents of the Bay of Bengal in the South West Monsoon, Journal of Royal Geographical Society 1862.

up for cultivation. The ground is so fertile that it is hardly necessary to plough it. The jungle is cut and burnt. Seed grain scattered at random yields one hundred fold with very slight labor. In other parts of the country the seed paddy is carefully taken up by hand and transplanted at regular intervals; at some cost and trouble. Probably the excessive richness of the lower region will bear the exhausting process indicated for a long time. But the extent of land available for cultivation on the banks of these creeks is comparatively restricted, as, in general, it is narrow and bounded by the water rising inside. There is thus a population widely scattered over a great extent of ground, and in the more settled parts it is really more numerous than is required for cultivation. Any possible extension of the cultivable area would here be immediately renumerative; and the question has pressed itself on the attention of the civil officers residing in the new district. Various proposals have been made to improve the condition of things, and as these will constantly recur from new arrivals, the more inviting ones may be noticed. One proposal by the Deputy Commissioner in charge was to cut new channels in the high rim of land round the edge of the Ma-oo-bin plain and thus to let in more water in order to accelerate the silting up of the interior. The process is attractive, and has in some cases of small rivers with a large ratio of silt, proved successful. It is known as the *warping* process. The writer was called on to report on this project. A very short calculation showed that by merely letting the water flow in and out from small cut channels, the silting up of the interior would take from 2000 to 3000 years Even if the space were arranged as a series of shallow reservoirs where the water could be kept till most of the silt settled, the process would be most expensive, and would take an enormous time. When warping does not occur naturally or under unusually favorable conditions, it is not possible, especially in a delta like that of the Irrawaddy. Another proposal was to embank the area. This is the only course practicable, and will ultimately be done. But pumping appliances must be used to remove the rainfall water. Whether this is now advisable can only be settled by close enquiry.

The warping process unsuitable for delta plains.

103. The whole of the steam-navigation is at present in the hands of one company, the Irrawaddy Flotilla, except that of the vessels of the Government of India, and of the King of Burma. The Flotilla vessels are side paddle steamers of 400 to 500 tons in the later examples, each with engines of about 200 nominal horse power. They are about 50 feet in width over the paddles, and draw 4 to 5 feet of water. In regular work they take each two flats one on either side of the steamer, of about 400 tons dead weight carrying capacity, the width over all being about 100 feet. Two trips up and two down are made per week, the one from Rangoon to Mandalay excluding stoppages averaging between 90 and 100 hours. The distance is over 500 miles. In the dry weather they take the Bassein creek and China Buckeer route. In the rains they shorten the distance by about 60 miles on the upward journey by taking the Panlang creek route, but as the upper entrance of this creek is lined by hundreds of trading boats at Yandoon, and the stream is only 500 to 600 feet broad with strong cross currents it is found inexpedient to take the short cut in return; so that the downward journey usually takes the dry weather route. On this line a delay of 12 to 24 hours is often caused by waiting for the tides, which are required to give water sufficient to take the steamer through the Bassein creek. The freight is about 10 Rupees per ton for heavy cargo like rice from the delta to Mandalay; but is much higher on miscellaneous goods, sometimes being as expensive as the freight from England to Rangoon. In the dry weather it would be a great advantage to have the Panlang creek kept open, and several investigations have been made into proposals for doing this. The obstructions lie mostly near the head of the branch at Yandoon; and consist of shoals of limited extent formed

Navigation of delta channels to main river.

Steamer dry weather route.

Monsoon route.

by deposits of alluvium in the falling stage of the river, generally about November or December. The depth of water is sometimes only a few inches on these at low tide, and boats have to wait for the rise of the tide to pass. Steam launches run from Rangoon to Yandoon but not beyond. The most obvious plan for dealing with these shoals is to dredge them. There is little silt in the river water during the dry season, and once removed they are not likely to reform. The channel once cleared would probably remain so till the next season. The dredge after performing its work could return to Rangoon or be elsewhere employed. A peculiar form of dredge boat carrying a steam navvy acting end on, so as to scoop out the shallow in front of it will be required, and such an instrument especially designed with the latest improvements would be invaluable in the delta. It would probably reduce the cost of such works as the proposed new Pooloo canal by one half; and, as will be afterwards pointed out, could be utilized on projected works required for the interior navigation and drainage of the Henzada Plain. The opening of the Panlang creek would not so much benefit the great steamer traffic for long distances, as it would the heavy boat and cargo traffic of the delta itself, which is heavily burdened by the immense detour, as well as endangered by being compelled to go so near the sea. And a new vessel, the first of its class, has just been brought out to work the heavy rice traffic of the produce from the embanked lands of the upper delta and Rangoon. Such vessels would benefit immensely by the improvement, the distance being practically reduced from one third to one half. Other proposals have been made for removing the shoals, such as the annual fixing of spurs or groins, as the water falls, to confine the current and erode the channel, but are not now recommended, as the erosive power of the water must be very small at that place in the low water of falling floods. Similar improvements are required, but not so urgently, in the mouth of the Pantanaw Branch, and, on the whole, it is considered that a floating excavator would be the very best and cheapest remedy to apply. The cost of this would probaby be Rs. 56,000 delivered in Rangoon.

Dredging proposed for Panlang creek.

Floating steam navvy recommended.

SECTION V.

The Pegu Sub-Yoma Plain and Yoma Torrent Streams.

The Pegu Sub-Yoma Plain Boundaries.

104. The Pegu Sub-Yoma Plain is bounded on the north by the Nawing River, which enters the Irawaddy at Prome; on the west, in its northern part, by the small meridional range of hills runing south from Prome; and in its southern, by the Hline River. To the east it is fringed by the high land and spurs of the Pegu Yomas containing the torrent streams running down from these hills to the Hline, and which give rise to the most difficult of the hydraulic problems affecting that plain. Streams south of the Thongzai Choung (choung=stream) occasion few difficulties of this kind. The hills from which they spring are generally low, the ridge averaging less than 600 feet in height, and their reception basins in the high ground are not large. As a rule these streams run with steepbanks and clear though tortuous channels through the the plains till they enter the Hline river, which carries without difficulty any silt they bring.

The Pegu Yoma Torrents.

105. This plain to the north of Thongzai is about 90 miles long by 15 broad, thus containing approximately 1350 square miles. Its slope from north to south is about one foot per mile, while it varies much from east to west; being steep near the base of the hills and softening to an almost imperceptible fall near the Hline River. It is intersected by several water courses running generally from north-east to south-west and ranging from the smallest size to over 100 feet in width where crossed by the railway line from Rangoon to Prome. A careful examination of these distinguishes them into torrents with reception basins in the hills and streams draining the plain land, with, in some cases, small tributaries from the outer slopes of the higher ground. The principal torrent streams taken in the order of their distance from Rangoon on the railway line, are given below with their reception basins in the hills, and their sectional area where crossed by that line as follows:—

Table 19.

Mile of Railway from Rangoon.	Name of Torrent stream.	Approximate sectional areas of stream at Railway line in square feet.	Approximate area of reception basins in square miles.
69	Thongzai	3,000	150
78	Lepadan	1,350	84
91	Sagaing	660	48
97	Minhla	585	36
103	Goy	405	50
105	Gamoung	600	40
117	Bobin	800	156
118	Minboo	660	40
128	Kantha	1,350	176
137	Shoay-lay	1,350	230

Questions regarding torrent.

106. The nature of the questions that have arisen regarding the condition of these streams cannot be better shown than by an extract from an official letter of Mr. Weideman, Assistant Commissioner of Tharrawaddy and now Deputy Commissioner, Henzada, to the Deputy Commissioner of the district, on the subject of which, the writer was called to report.

Mr. Weidemann's charges against the Forest Department.

From G. E. WEIDEMANN ESQR., *Assistant Commissioner to* J. K. MACRAE ESQR., *Deputy Commissioner, No.* 32-4, *dated Mengyee* 3*rd August* 1877.

"SIR.—I have the honor to forward herewith an estimate for making a bund, along the Kantha Choung in order to check the overflows from that stream."

"The choung forms a portion of the northern boundary of the Tharrawaddy, and goes by various names, at various portions of its course. At the place where it is proposed to erect the bund, it is known by the name of the Gongin Choung."

"The portion proposed to shut in, extends roughly for two miles on each side of the road between Tapoon and Poungday.

"Owing to the destruction caused of late years by the floods from the Kantha, portions of the road to a considerable distance north and south of that stream have been rendered impassible, and so hopeless is the repair of the road apparently deemed under the present condition of the Kantha, that the bridge over the stream itself has been this year dismantled. The effects of the floods are seen within a mile of Tahpoon, four miles from the Choung, and equal disaster is I believe caused on the Poungday side."

"It must not be imagined that the stream was always subject to overflows. If it was so the P. W. D. would hardly have been rash enough to undertake the construction of the road between Tahpoon and Poungday the state of which it is now so melancholly to contemplate. Four or five years ago I am assured the depth of the stream in the rains was the length of a bamboo.

"The channel is now reduced for some distance to a depth of three or four feet or even less, through which a man can easily wade, and in the middle of which buffaloes can wallow. Such a channel is obviously incapable of carrying off the same volume of water as heretofore especially during the freshes which come down from the hills at intervals during the monsoon. The country on both sides is therefore subjected from time to time to a rush of water of considerable violence, which has not only partially destroyed the only road besides the Prome road which has hitherto existed in the Tharrawaddy, but has also laid waste a large tract of land formerly devoted to cultivation on both banks. The annexed Estimate shows 500 acres as area damaged on the south side alone and this estimate I should imagine from the look of the country to be no way exaggerated."

"The cause of all this is I believe not far to seek. It is the same which has operated so disastrously on most of the hill streams of the Tharrawaddy, but in no case, not even in that of the Beeling, so disastrously as in the case of the Kantha. It is simply, if unanimous testimony is to be trusted, the careless manner in which logs of timber are floated down these streams from the hills above. The fact indeed is so notorious that the officers of the Forest Department do not attempt or care to deny it."

"It is true that in his letter No. 1202-110-6 C., dated 25th March 1876, the Assistant Conservator Myanoung invoked the aid of my predecessor in preventing villagers from throwing refuse into the timber conveying streams, which he said is one of the chief causes of the formation of the obstruction and the consequent inundation of the country. It is possible that this may be true, but the original sin lies at the door of the people who extract and float timber, mere refuse would be carried safely down any one of the hill streams were it not that here and there it meets a log jammed in its path. The two together then unite and arrest the silt which the stream carries down with it, and which instead of being carried off is thereby precipitated with great rapidity and in great quantities into the bed of the current. From this moment the closing of the channel is merely a matter of time, and the closing of the channel leads naturally to inundation."

"It is however not of much use to resort to recriminations. The mischief has been already done, at least in the case of the Kantha, and it remains to consider a remedy."

"The most obvious remedy is to dig out the bed of the stream, when this operation has to be carried out along a length of some three or four miles, the cost is so great that it is not likely to be undertaken except as a last resort."

"The plan now advocated, is to run parallel with the stream a cheap and close fence, along the inner side of which during the overflows a natural embankment of silt will be formed by the operation of the current. That silt will thus form is shewn by experience. During the inundations the stream has exerted greater violence in some parts than others, thereby wearing away the bank and forming ditches which run a long distance into the country, and help to spread the overflow. To close the entrance to these channels the villagers have already erected wattled fences which have served the purpose of arresting the silt and damming the channels. In erecting a similar fence for a length of four miles care will of course be required to make it strong enough to withstand the first rush of the shallow stream as it brims over. When silt has once formed in sufficient thickness the fence will have done its work."

"The effect of bunding one bank of the choung will of course be to leave the other (the Poungday) side more exposed than ever. This could be avoided by bunding both sides."

"If this is done, and the stream once more confined to its own channel not only will it be possible to resume cultivation along its banks, but the force of the water not being dissipated as heretofore, will it is trusted be capable of again scouring out the old channel, and accomplish of its own accord a work which could only be carried out at great expense by labour."

* * *

I have &c.,

(Sd.) G. E. WEIDEMANN,

Assistant Commissioner.

Controversies as to cause of damage to the Torrent streams.

107. This letter accosts a topic which has caused much bitter controversy for the last 25 years, or ever since the Forest Department commenced its operations, and in which the officers of that branch of the Government service have been accused of damaging nearly the whole of the upper part of the plain under consideration by the methods in which their operations have been conducted. Not only the civil officers, but the Engineers of the Railway and the Roads in that quarter have taken up the question from time to time and as the works under their charges have suffered, have assailed the Forest Department as the cause of the evil. The forest officers have had not only to undergo the loss of much valuable timber covered by the silt, and hundreds if not thousands of tons of the best teak have disappeared in swampy sediment, and to incur the expense of opening up fresh channels occasionally, but have had to defend themselves from the charge brought against them of being the sole cause of the evil. There has been a great expenditure of controversial power, but the condition of things has not improved. Indeed, as the late date of that letter and its contents show, things have got worse, and are apparently intensifying to a climax.

The writer's connection with this question.

108. The writer had charge of the roads from Prome to Thongzai from 1865 to 1868, and obtained an intimate personal knowledge of the whole of that plain country. He constructed the road referred to from Poungday to Tahpoon, and laid out, and in part constructed, the embankment on which the present Railway is carried from Thongzai to Poungday. He had not only to

examine the question in connection with those works at that time; but was deputed to report on other injurious results of a similar nature principally in the lower part of the Shoaylay choung, where a canal had to be excavated in 1867. He then took much the same view that is given in the letter quoted—that the forest officers are primarily responsible for the damage done—but a further study of the question has brought some modification of his views, which at this interval of time, tend to be more impartial.

109. The true cause of the unhappy state of the country is due to the soft nature of the strata in the reception basins of the torrent streams of this part of the Pegu Yoma. The testimony of the most competent observers on the subject is conclusive. Mr. Theobald the Geological Surveyor's statement has already been referred to. Mr. Kurz the botanist crossed by the head-water of the Lepadan or Beeling Choung in 1871 to the Sittang side; returning by the reception basins of the Minboo Choung. He afterwards crossed to Toungoo by the Shoaylay feeders; his object being to examine the botanical characteristics of the Forests. These reception basins of the Pegu Yoma torrents yield much of the best teak of Pegu and contain numerous other useful trees; which are in great request locally. Mr. Kurz was a thoroughly trained scientific observer, and notes all the features on which the character of the forest depends. At every step of his route he describes the geological condition of the country and a very few extracts will give an idea of the whole, In one place, in the lower part of a feeder of the Lepadan creek, he notes the existence of laterite, an iron clay:—"26th January 1871. Here I passed the laterite stratum. This is the first instance that I met with of true diluvial laterite within the Yoma sandstone hills. It is probably an ancient river bed. The upper layers consist of so decomposed a mass that it is not easy to say whether it is really decomposed sandstones or sand consolidating into sandstones. Any how it is stratified and the ferruginous matter has penetrated to the low stratum." In almost every other instance he has only to speak of sandstone calcareous or silicious. It is always more or less decomposed at the surface by the action of the atmosphere. Thus 16th February:—"The soft silica sandstone alternated with some of calcareous sandstone and slates," 18th. "Towards the Payleoma Choung calcarious sandstones became more conspicuous alternating conformably with soft sandstones and slates." 27th (on the crest of the Yoma in Minboo.) "The formation was calcarious sandstones in a very decomposed state, which was there transformed into a smoky-grey coarse permeable sandstone, variously interlaid with shales and silicious sandstone." These descriptions are repeated without much variation for the more northern parts of the Pegu Yoma and reveal a condition of the reception basins of the torrents which render them highly susceptible to the excavating power of the rain-fall.

Mr. Kurz on the Pegu torrent reception basins.

Soft and friable nature of the sandstone.

110. We have in this soft and easily decomposable condition of the rocks of the Pegu Yoma the primary cause of the evil, a cause which exists independently of all human agency. The extent to which its effects may reach can be inferred from the position of the Hline river, the general drainage channel of the country, at such a distance from the hills. This distance clearly indicates that the process of excavation and re-deposit to which the existence of the whole plain is primarily due, must have always proceeded with great activity ever since the Yoma rose above the ocean level. Whether these effects have been intensified or can be moderated by the hand of man is an enquiry of the utmost importance, which becomes more pressing every year. A general statement of what has occurred within the last few years on the channels of the principal torrents will assist in elucidating or clearing the way for an answer.

The great width of the Pegu Sub-Yoma plain due to Yoma deposits.

111. The Hline river marks out the lowest part of the plain. Its most northern branch is called the Zay Choung, which has a torrential reception basin of some 40 miles within the lower spurs of the Pegu Yoma. A further gathering ground of 60

The Hline river Upper sources.

square miles in high plain land brings it to the Mahathaman plain east of Prome where the bed of deposit of the silt is found. On first proceeding to take charge of works at Prome in 1865, the writer was directed to examine and report upon injuries to cultivation and to irrigation works from the deposition of silt in this part. No copy of the report sent in is at hand; but as far as memory serves the substance of it was as follows. A network of irrigation channels had been constructed by the voluntary action of the people under the supervision and direction of General David Brown, then Deputy Commissioner of Prome. These extended some 8 or 10 miles over the country, the principal ones being not over 6 feet deep by 10 feet wide. At first they were very successful, and they were thoroughly appreciated by the people, who long after General Brown left Prome endeavoured to keep them efficient. They were derived from an elevated point of the channel of the torrent, which filled them with pure silicious sand after freshets. The cone of deposit from this torrent spread over the flat country, not only injuring the cultivation, but ultimately succeeding in stopping the irrigation. The sand was scooped out time after time, but at length overpowered the available force for removing it. Great anxiety was displayed by the people to renew or improve the channels, but no action was then taken; and it is feared that the experimental irrigation has not been renewed.

Irrigation of the Mahathaman plain.

112. From the Mahathaman plain southwards the Hline flows in a broad and shallow undefined channel through a series of lakes or swamps. The most southern of these is known as the Eng-ma ဝှဲး (large lake), some 10 miles long by 4 wide, after heavy and continuous rains. They shrink very much in the dry weather, but effectually prevent cultivation. They are caused by the cone of deposit of the Shoaylay or Wetpouk Choung being thrown into the bed of the Hline where it joins it, some 25 miles south of Prome. The water after being reservoired in these lakes flows sluggishly through the southern outlet. Two or three miles above the Shoaylay junction the Prome and Poungday road crosses the Engma swamp. The writer in 1866, proposed a bridge with a single waterway of 40 feet across this, and the waterway was ordered to be reduced to 35 feet, which with a depth of 12 to 15 feet forms the sole exit to the drainage of over 300 square miles of plain country. This exit would be too small if the drainage were put in proper order; and if ever this is done a new bridge will have to be substituted with much larger waterway.

The Engma lake.

113. The high flood level of 1875 at Prome, is about 93 feet above mean sea level (M. S. L.); and according to Colonel Stoddard's levels the bed of the Engma swamps under the bridge is 58·5 feet, and at the junction of the Shoaylay and the Hline, it was in 1869, 57·38 above the same datum level. In 1866 and 1867 it had been raised so much that the Engma lake expanded and swamped large tracts of cultivation on its borders; and a channel was cut by the Civil Officers through the bed of deposit. It lowered the waters somewhat, but was of too small dimensions, being not over 6 feet deep and 8 or 10 wide, to effect much improvement. Large tracts of good ground were also submerged by the silt. The writer had on different occasions to examine these tracts. The forest department Officers also cut channels to relieve the Shwaylay Choung and to provide passage for their timber through it. Mr. Ring, Executive Engineer, has surveyed within the last few years the region damaged, and states that it has much extended.

Obstructions caused by the bed of deposit of the Shoaylay torrent.

114. He also had to remove the bridge on the Poungday and Tahpoon road crossing the Kantha Choung and referred to by Mr. Weidemann. The writer has been able to consult both these officers lately and to learn some of the latest changes occurring in the beds of deposits and channels of the principal torrents since he personally examined them previous to 1868. An old Burman wooden bridge stood on the site of the newer one, which was put up

The Kantha Torrent. Advance of its bed of deposit.

after the construction of the road. Its position was about 8 miles above the junction of the Kantha stream with the Hline which it enters about 10 miles below the Shoaylay. The floor of the old bridge was some feet below the ground level; the channel and bed were clear, and the floods rarely, if ever, topped the banks. The new bridge was made higher. The neighbouring plains were almost never flooded near the stream previous to 1868. The new bridge was on wooden piles and did not change the regime of the stream in any way. In 10 years the whole lower course of the stream has deteriorated. The bed of deposit has advanced steadily up stream, filling the channel, and as the water overflowed, the sediment has been deposited over all the cultivated ground. It is unfortunately mostly silicious sand and thus does not benefit the ground. It is not possible to state the exact area of ground injured, but in all it is some thousands of acres. The head of the bed of deposit is now a mile or two above the bridge. The channel beneath this got filled, and the structure had to be removed. The road constructed in 1867 has been partially destroyed, and some 30,000 or 40,000 Rs. spent in its construction wasted. Mr. Weidemann states that the stream having once shed its silt resumes a single channel below its new bed of deposit; thus having cut itself a course through its former silt. There is every prospect of the cone of deposit going still further up stream to reach the railway line, when it will render the bridges there useless; and new waterways must be cut. The necessity for effectual remedial measures with both the Shoaylay and Kantha torrents is thus of the utmost urgency.

The Bobin torrent.

115. Both the Shoaylay and the Kantha have their reception basins in the higher parts of the Yoma; the area of the former being about 230, of the latter 176 square miles. The size of both, in 1868, where crossed by the Prome and Poungday road and by the railway, was similar. The writer had to design iron bridges for these, the spans being in each case 96 feet; and the greatest depth of water about 20 feet, their cross sections being approximately 1350 feet, thus giving a smaller ratio in proportion to drainage area for the former. The causes of this will be discussed presently, but they are now brought forward to contrast them with the cross section of the Bobin Choung in 1868, where crossed by the railway line. This was then only 800 square feet, although the reception basin of the principal branch has an area of about 196 square miles, and is immediately contiguous to that of the Kantha in the higher Yoma. This small channel was entirely due to the reception basin having advanced above the line of the railway. It had done so long before that line was laid out. The channel of the principal stream before it leaves the hills near Bobin is about 200 feet wide and 15 to 20 feet deep, but it was broken up into several smaller channels on the cone of deposit, and inundated the whole country. A large number of waterways had to be given where these crossed the embankment, which they mostly did in 1868, following the line of the Wet choung; but, since 1868, the whole course of the stream has been changed from where it leaves the hills, and one of its channels runs due east to join the Choung Souk or Minboo Choung near Zeegon. Probably the bed of deposit had ascended as far as the exit gully from the hills. The water is still spread in several channels and inundates the country, but the one channel serves for timber carrying purposes. No positive harm has been done to cultivation, for the simple reason that the stream has never permitted any to exist within the limits of its devastations; but if it could be controlled a larger tract of good ground would be rendered available for cultivation close to the railway. The Minboo and other streams from the outer flanks of the Yoma in this part have a total basin area of about 40 miles on the hills, and beyond inundating the country in floods do little harm.

Origin of the damage to the Bobin Choung.

116. It is difficult to say when or how the Bobin Choung commenced its divagations It can hardly be due to the action of the Forest Department, as so far back as 1857-60, when the operations had only been a few years in progress the Pegu Forest Report for that year says:—"this stream has had during the last 50 years three outlets; the present one, Sean Choung was form-

ed 3 years ago in a western direction, but this outlet is only open for about 6 miles beyond the old obstruction, where it is rapidly being blocked up by sand and rubbish, so that now a canal is under construction opening out one of the old courses of this stream in a south west direction." This opening out of channels through the beds of deposit is only of temporary advantage while the silt brought down is so much in excess, and has been repeated many times at a great cost of money. Dr. Brandis, Inspector General of Forests, writing in 1856, says. "Obstructions are very frequent in many tributaries, especially in the lower parts of their course, when their beds are not in deep ravines, but shallow, and not seldom spread out into numerous branches. The origin of the accumulation of trees, branches, sand &c., is either an accidental stoppage in the bed of the river, caused by a fallen tree, or by a few logs of timber not removed in time before the fall of the water or it is the over-luxuriant growth of jungle which takes possession of the bed of the river, narrowing its channel and dividing it into several branches."

The Minhla Torrent.

117. He mentions the Minhla choung as an instance "where every log has for a long distance, to be dragged overland by buffaloes, before reaching the lower unobstructed part of the river." This stream at present receives four separate torrents from the higher parts of the Yoma; the Too, the Gamoung, the Goy and the Minhla. Formerly the first had a separate course to the Hline, but has now joined the Too and Gamoung above the Railway line. The reception areas appear to be about 30, 40, 30 and 36 square miles respectively. The Minhla, which formerly was troublesome, has now ceased to be so in the higher parts; but the Goy choung has formed a new bed of deposit just below the Railway line, and is rapidly filling its channel there. A large tract of country in the vicinity is annually submerged with much loss to cultivation, which is still attempted in a precarious manner. The sectional areas of these streams at the Railway were about 600, 405, and 585 square feet in 1868.

The Lepadan Torrent.

118. The last of these torrents to be noticed is the Lepadan Choung which debouches at Beeling on the Hline. The condition of this stream has deteriorated much within the last few years in the lower parts of its channel. Mr. Weidemann has had to report on its devastations. Its bed of deposit has steadily advanced up the channel to beyond the Railway, where the large creek has been partially filled. This in 1868 had about 1,350 feet section and was a fine clear stream. Now several channels break through or over the alluvium above the Railway, and have necessitated a re-building of several bridges with increased width of waterway. Damage has been done to a large extent of country and probably 3,000 to 4,000 acres of cultivation in the immediate vicinity ruined. The reception basin of this stream is about 84 square miles.

General deterioration of the Pegu Torrents.

119. There is thus clear evidence of several changes, and nearly all for the worse, in the condition of these torrents, and in the country contiguous to them. The beds of deposit have in many cases raised the channels of their own stream, and have advanced towards the hills. In other cases the beds of deposit may have remained near the Hline, but they have then either injured that river, or lie wholly within the area submerged by the great annual inundation, where their vagaries are not noticed. It is likely that in almost every case the need of amelioration will become more pressing from year to year. Previous to 1868 the Tharrawaddy district which is principally affected, was rarely visited by Europeans. No European officer of any kind was permanently stationed there; and the writer only occasionally heard of district officers from the other side of the river passing through. Now it has been formed into a new district, with a complete staff of its own. The Railway runs through it, bringing numerous visitors, and a great accession of settlers. Several Europeans and Americans reside there. It is getting noticed that the district, especially near these torrent beds of deposit, is unhealthy. It has long been

known that the neighbourhood of rivers in the depositing state is unhealthy; and for the last year or two, since the Railway has been opened, cholera and other diseases occasionally rage up and down the line. A general scheme for improving this state of things is therefore worthy of consideration.

Three alleged causes of this deterioration.

120. The causes alleged for the progressive deterioration are three.—1, The floating down of logs of teak &c., by the Forest Department, which, getting entangled in the channel of the stream in a falling freshet, as described by Dr. Brandis, get covered with silt and cannot rise with the next flood, which then tends to increase the obstacle. 2, The Forest Officers allege that the cutting down of trees and jungle for toungya cultivation is the principal cause. This is a cultivation practised by hill Karens who cut down or set fire to the trees and jungle of whole hill sides in order to bring up a single crop; the operation being repeated next year in another place. 3, Some of the people allege that the embankment works on the western side of the Irrawaddy have increased the Hline floods, and by backing up the flow from the torrent streams have caused their beds of deposit to advance higher up. All of these causes, so far as they exist, are efficient, and tend to produce the effects described there!

First cause considered. Damage by forest operation.

121. That the first cause does exist, is undoubted, but it is far from being the sole one. Dr. Brandis admits and correctly describes the process. It has been the unremitting effort of the Forest Officers to overcome the evil, both on their own account and on that of the country affected. That they have not succeeded in their efforts is owing to other causes of more potence having been conjoined to produce the effects. This would soon be seen to be the case, if all the timber floated by these streams were caught and taken out near the railway for conveyance by it instead of being floated down to Rangoon through the Hline. The experiment might be tried on one of the smaller streams where the injuries to the country are grave; and if found at all successful, and the cost of extraction and conveyance not too great, this operation could then be extended to all the other streams.

Damage through toungya cultivation.

122. But, in the writer's opinion, the view advanced by the Forest Officers gives a more correct indication of the immediately efficient cause of the evil. The soft nature of the rocks must always have been, and will always be the primary difficulty to contend with; but the progressive deterioration of the lower plains has advanced *pari passu* with the spread of the hill cultivation, which has increased with the general prosperity of the Province. Mr. Kurz in his journals describes the effects of the toungya cultivation in the torrent reception basins of the higher Yomas. Thus 18th February 1871. "* * * We ascended a ridge containing toungyas. A tay [small hut] stood here formerly but now it was full of bamboos, half burnt logs and rank vegetation. * * The whole ridge showed nothing but deserted toungyas until we reached the main range of the Yoma" He found fires raging all through the forests. Thus 25th February. "I observed a tiger crawling along a thousand feet below, who was doubtless retreating before the jungle fires which raged over the valley." Again 27th February "unfortunately these like all the other ridges we had passed, had been swept by jungle fires * * Below in the valley destructive fires were raging and the dense volumes of smoke prevented me from noticing the arrangement of the numerous spurs which run down from the main range." These fires spread over the whole of the hills in the dry season, and the advance of the burning line can be seen on the mountains for miles in dark nights. They are caused by the cultivators who clear the jungle by them, and then leave them to spread. They destroy all the shrubs and lower vegetation, leaving often the stronger trees standing, which are sometimes specially burned by the Karens. In the journal of his journey with Dr. Brandis in 1868, Mr. Kurz notices the results of this destruction on one of the eastern valleys. 29th February 1868. "These forests were soon re-placed by hill poonyahs which continued all along leaving

only a few patches of wretchedly cut out upper mixed forests. The whole country as far as the eye can reach is deprived of all its forests and only in a few sheltered localities, or rather where the inaccessability of the rocks prevented a renumerative toungya cultivation, are patches of forests still to be seen," 12th March 1868. "The whole Myetguan valley is perfectly denuded of its forests. Only a single small patch of evergreen forest was met with * * the path wound up and down through endless toungyas. The opposite watershed also appeared to be woodless. What a destruction of forest must have gone on here since 1859! Dr. Brandis' sketch map of the teak localities in the Tenasserim and Martaban Provinces represented the whole valley as one teak forest of 36 square miles, and now hardly a single teak can be seen, in fact only scattered trees which partake of the character of an upper mixed forest are left to indicate their former existence. Such destruction much sooner or later become the subject of serious consideration."

Value of forest operations in preventing damage.

123. In the series of facts the existence of which are above indicated, lies the greatest source of injury to the torrent streams and the plains. So far from the forest officers having been the greatest offenders, their reports are a long series of protests against the evil, and through their representation the first step has finally been taken to prevent its further spread and in some measure its recurrence. The fires and the axe have denuded immense tracts of the soft strata of the hills of their natural coverings and protection. The binding of the decomposed soil by the roots, and the shelter from the rainfall by the thick foliage of the vegetation have been lost with the forest, the shrubs and the grass which clothed it. The influence of the larger trees in protecting the soil has been much disputed, but the balance of authority, especially among botanists and engineers is in favor of their utility. The late M. Cezanne whose republication and continuation of M. Surell's studies on torrents has before been mentioned, thus sums up the effects of the larger forests :—"The moderating action of forests is only certain and preponderating in those cases where without them, the sloping ground would be ravined :—"Generally speaking, and with a few exceptions noticed, forests are unfavorable to evaporation, but they facilitate infiltration; and they only retard efficaciously the flow of water in those cases where they stop ravining."

Studies of M. Surell on the prevention of ravining.

124. The studies of M. Surell were written in 1838 and printed in 1841. They were not followed by much practical result till 1860, when a law was passed in France authorizing the re-foresting of the mountains where the ravining action of the torrent had caused most devastation. This process was found to be both costly and slow; and tended to promote the welfare of the plain lands at the expense of the mountains, and a new law was passed in 1864 authorizing other measures, principally of grass culture *(gazonnement)* in the threatened districts with a view to preventing ravining. The operations in both cases were entrusted to the officers of the Forest Department of France, and the success attained was beyond all hopes. The worst regions were taken up by the Government or proclaimed, so as to interdict all interference of the neighbouring population. In 1868 the annual report of the department showed a marvellous progress in the good results achieved. The re-foresting had been combined with the grass culture. The report says the peoples interests had been consulted in giving them pasture for their beasts and this had converted hostile views to satisfied ones. "In going round the perimeters in course of regeneration, the transformation and consolidation of the soil can be appreciated, and it may be foreseen without utopian dreams, that certain portions will shortly be cultivated and be converted by irrigation into natural meadows. By the consolidation of the soil and the vegetation, the torrential characters so well described by M. Surell have disappeared. The waters, even in time of rain, have less silt. * * There are no more violent and swift floods, the waters in arriving at the cones of deposit, are not overcharged with matter; they encase

Results obtained in France.

themselves naturally in their deposits. In raising and transporting further on the materials brought down, they open out boulders of great volume, and form for themselves a fixed and solid bed. The divagations are less to be feared and are less dangerous, and the dwellers on the banks can protect themselves at little expense." Several specific instances are quoted, where large works projected to protect the imperial roads near the cones of dejection of torrents, had been rendered unnecessary and a very small expenditure had sufficed. "The benefits to the lands near the cones of deposit in the plains are immense. Not only are the proprietors freed from costly and precarious embankments, but their heritages, having no longer to fear being buried under the gravel, take a determinate value."

Application of protective operations in Burma. Reforesting and grassing.

125. The first steps in the amelioration of the torrents of the Pegu Yoma has been taken by the Forest Department in the protection of its own interests. The whole of the districts in the reception basins not actually under fixed cultivation, have been proclaimed, and the village lands demarcated. The toungya cultivation, formerly so destructive, is now generally prohibited in the forests. Possibly by natural agencies the grassing and rewooding of the slopes and torrent beds may take place; but, if not, the agency of that department might intervene with advantage, and by a careful selection of those portions of the basins of reception where the ravining is at present most destructive, for operations of direct culture of the most suitable grass and shrubs, attain as satisfactory results as those obtained in France.

Other operations in extreme cases. Barrages.

126. In the worst cases of ravining, which are generally of very restricted area and which often are the sole causes of the worst features of the destruction in the plains below, by the amount of silt they yield, stronger measures are necessary. Barrages are the most useful of these works. They consist of various kinds of dams thrown across a ravining channel, and vary from simple fascines of grass or reeds pinned down, to more elaborate works of wood piling and stone. In the torrent of St. Martha whose perimeter embraced 530 hectares (1310 acres) no less than 800 barrages were constructed, differing considerably in dimensions and in the mode of construction. In the present condition of this country it would perhaps be unadvisable and unnecessary to carry out such a system as this, but some measures of the kind are undoubtedly necessary. The able officers of the Forest Department would doubtless be able to point out and suggest the most economic and efficacions remedies of this kind which could now be advantageously employed in the Pegu Yoma. If, as is not improbable, it may eventually become expedient to employ irrigation over the Pegu Sub-Yoma plains, the Engineers who carry out the works can readily devise means of combining extensive barrages with dams to store up the water requisite.

Storage dams for water.

The writer's previous recommendations on this subject.

127. The writer has already advocated this being done. In his report dated Prome 11th April 1868 he says, para 73, referring to the sources of the inundation water of the Hline. "The second source is from the rain-fall in the hills, and the water from there is carried off in several well defined channels, the banks of which, being always higher than the country on both sides, prevent water flowing into them from the surface of the plains. The water occasionally comes down these streams with a rush; completely filling them, and spilling over their banks as the velocity of the water is checked by the friction of the bed of the creek. This spill regulates the quantity of water actually delivered by these creeks to the Hline, as it joins the reservoir of the plain country and flows in slowly. These streams are of great importance, as they may be utilized in providing water to irrigate the plains, by bunds thrown across their course in suitable places before they leave the hills. The time will come when the whole of these may be required. Already in the highly cultivated Mahathaman and Poungday sub-districts to the east and south of Prome,

water is a great want, and several small works in the shape of dams and canals exist. The retaining for irrigation purposes the hill waters of this district is already a desideratum." It was with reference to this paragraph that the Government of India ordered further enquiry and report on projects for irrigation to be made. No opportunities for doing this have been afforded to the writer, whose work has since lain in the southern parts of the region. But that some such works in the northern part of the plain under consideration are urgently needed may be inferred from the last statement published in 1878 in the Government Gazette of the Prome district crops. The year's rain-fall had been about 48 inches at Prome, very little below the average, yet the Gazette says "Prome district fair average crop in half of Mahathaman townships; Shoaylay below half the usual out-turn, a nearly total failure in Engma and Poungday." These townships make up the whole plain north of the Kantha Choung. A grave loss which might have been averted by irrigation, is here recorded to the people and to the Government.

Irrigation projects urgently required for Pegu Sub-Yoma Plain.

128. It is impossible without more data than the writer possesses to venture on any specific proposals for the irrigation of these plains; but he is convinced that any water required for the purpose must be drawn from these Yoma torrents. They are more than sufficient to supply all possible needs, and the work can be combined with the improvement of the basins of reception. Colonel Stoddard, adverting to the above proposals, advocated a counter scheme, which was combined with a canal derived from the Irrawaddy at Prome, and which was to serve for navigation. The canal for navigation was to lead to the Hline in the channel of which he proposed (1) "to throw a weir of sufficient height across the Myitmaka or Hline above the junction of the Wetpouk, and cut two main distributary channels or rajbuhas, east and west, and running on the highest ground that can be reached by the water, and generally parallel to the course of the Myitkmaka itself, with smaller irrigating channels leading from those in an oblique direction towards the Myitkmaka or Hline, which itself will receive the whole of the drainage and carry it off. Should one weir not be enough for the whole distance traversed by the Hline, one or two more might be constructed at any points where it might be desirable to raise the surface of the water; and the navigability of the channel preserved by constructing locks alongside of the weirs." This proposal, if carried out, would raise the Eng-ma lake still higher than it now is, and intensify the evil already felt from the inundation there, while as the lake lies in the lowest part of the country requiring the water, no supply could be obtained from the lake for the fields by gravitation. In other respects, if, for instance, the Nawing Choung were rendered the source of supply, the project is practicable, and would have the advantage of uniting the irrigation schemes in one grand and comprehensive design, with a single head works, and two principal canals, one leading down the Pegu Sub-Yoma Plain another down the side of the Irrawaddy to irrigate the western plain of the Hline valley. The work would be costly, if efficient; and, in the writer's opinion, premature. The lower Hline valley plains have not yet been redeemed from inundation. And no need has yet been made out for a grand general scheme of irrigation. It is not needed in the lower delta, where half the ordinary rainfall can ensure a good crop. And the Pegu Sub-Yoma Plain, wherever irrigation could be shown to be a necessity, could be dealt with most economically by small and local schemes for providing the water, each from the nearest torrent, in conjunction with the protective works advocated. Beyond these general considerations the writer cannot now go.

Colonel Stoddard's proposals.

Other improvements required.

129. The protective works of grass culture, barrages and irrigation dams on the reception basins of the torrent streams of the Pegu Yoma will not of themselves be sufficient for the amelioration of the Sub-Yoma Plain. Without them, nothing can be done in the plain itself. No embankments for streams, or canal cutting, or

(1).—Stoddard, Colonel. Report on Irrawaddy Investigation in 1869.

diversions of channel will be of the least avail in the lower plains, if the ravining and excessive excavation of earth is not stopped in the reception basins, but this once achieved or in fair progress, other improvements become possible, and are required. The creeks when they once enter the plains commence overflowing and spread their water and silt over the whole country in their neighbourhood. This gradually diminishes the amount of water passed on through the channel in successive lengths of its course. The sectional area of the channel also diminishes so that if cross sections were taken at every half mile of any of these creeks from its exit from the hills to its entry into the Hline, it would be seen that the capacity and contents of the creek in floods lessens continually towards its mouth. Practically the bed of deposit commences at present at the exit gully, though on a small scale. A comparison of the basin areas and the capacities of the various streams where crossed by the Prome road and Railway, as taken by the writer in 1868, makes the discrepancies of the carrying powers of the channels manifest. These are

Table 20.

Torrent Streams Pegu Yoma.	Square miles in basin.	Square feet in Channel Prome Railway line.	Ratio of feet per mile.
Thongzai	160	3,000	188
Lepadan	84	1,350	161
Sagaing	48	660	138
Minhla	36	585	163
Goy	30	405	138
Gamoung	40	600	120
Bobin	156	800	51
Minboo	40	660	165
Kantha	176	1,350	77
Shoaylay	230	1,350	59

Comparison of torrent basins and capacities of channels.

130. The stream with the largest capacity at the Railway line is the Thongzai, which has 188 square feet of section naturally for every square mile of country drained. This stream is in fair condition, though in certain parts it spills over its banks, and diminishes in size as it reaches the Hline. It continually excavates and re-adjusts its channel throughout the length of its course in the plains. It has, notwithstanding a very tortuous channel, a comparatively short length to run after leaving the hills, not more than 10 or 12 miles in the plain. Possibly its immunity hitherto has depended on this shortness of course. The streams with the least waterways at the railway line are the Bobin and the Shoaylay, both of which were in 1868 in the worst condition of all the torrents. The Kantha must then have been deteriorating in the lower inundated country, where it escaped notice, since it had only 77 square feet for each mile of reception basin. A study of these basins in the map shows that they are in the same condition with each other so far as the facility for gathering and distributing the rainfall is concerned. We know that geologically the strata are the same throughout; and though the rainfall progressively diminishes from south northward, it does so gradually and slightly. If this were the same in all, the ratio of the channels when they leave the reception basins must be nearly the same. No accurate measurements are available, but it is known that all the above streams including the Thongzai one are larger at the exit gully than in the plains below. And it is an indispensable condition to the reclamation of the plains from inundation from these streams, that the capacities of their channels should be enlarged throughout their courses in the plains to that which they have at the exit gully. Otherwise they will continue to spill over their banks and lose both water and the excavating power over their channels. When once the water issuing from the hills is freed from its excess of silt by the measures indicated, it will be necessary to guide by light embankments the waters in the channel through the plain. The fall from

Regulating operations necessary for all the torrents.

the hills is great enough to give a dynamic head to the stream in every part of the plain sufficient to allow for carrying the water and at the same time excavating the channel to a proper size. Possibly groins and guiding piers of a light kind may be necessary at first to keep the action more on the bed than on the banks; and each stream will require regulating. But if this is done all these torrents will eventually excavate for themselves channels large enough to pass all the hill drainage they are called upon to carry without damage to the intervening plain. The experience gathered on the torrents of the Alps and other countries justifies these expectations.

Surface slope of the Pegu Sub-Yoma plain.

131. That the slope will be sufficient for the streams may be gathered from the levels given in Plate VII., Figures 5, 6, 7, and 8. Fig. 8 shows a section across the delta below Henzada. The last part of it gives the fall from the base of the hills near Lepadan to the Hline. The fall in the first $3\frac{1}{2}$ miles is 9 feet per mile. In the next four it is about $4\frac{1}{2}$ feet; and in the last four it is only $1\frac{1}{4}$ feet. The last has been proved sufficient for excavating a channel, as the ordinary drainage streams flow in clear well defined channels. They have little silt to convey and vary but slightly in their courses. The excess slope in the higher land is used by the stream in working out sinuosities in its course, as evidenced by the Lepadan Choung. If this is moderated by regulating works, the excavation will be utilized in enlarging the channel. Further north the slope across country is smaller, as the plain is broader. The levels taken from Poungday to Tahpoon show an average fall of over 3 feet per mile in 10 miles. For the last 4 miles from Tahpoon to the Hline it is about $1\frac{1}{4}$ feet per mile; but the banks of the stream are here higher than the plains. The slope given is what is available for both the Kantha and the Shoaylay Choungs and is ample to enable them to clear out their channels, provided the water can be delivered to them in the plains not overcharged with silt; and regulating operations are put in hand to control them.

Extent of plain to be ameliorated by these operations.

132. The portion of the plain which would be ameliorated by these operations conducted to a successful issue lies between the limits of the ordinary inundation of the Hline and the base of the hills. Deducting 500 square miles from the whole extent of the Sub-Yoma plain for this inundation we would have over 800 square miles of plain land placed in security from the torrents. At present from one-half to two-thirds of this is either entirely uncultivable, or in a precarious condition from these sources. When the roads were made in 1866-1868 cultivated land could be obtained, and was taken up for the roads at from 12 to 25 Rupees per acre. The carrying the railway line through it has immensely increased its value and now near towns and large villages it occasionally brings from 10 to 20 times those amounts. The population is largely increased, the demand for land is great, and there is no doubt if it could be cultivated all yet available would be rapidly taken up by the people. From the sandy nature of the deposits of which it is constructed the land is not so good for rice, as the lower lying areas the Irrawaddy; though with irrigation and other crops than rice it might be made much more valuable. But a comprehensive scheme dealing with it as a whole is required to bring out its value; and the principal points calling for notice and the methods recommended have now been brought generally under review.

Their cause of deterioration.

133. The annual inundation of the Hline valley from the Irrawaddy no doubt has considerable effect in retarding the flow of the torrent streams and thus causing them to deposit their silt in so many deltas on the river banks. And it is undoubted that this inundation has increased of late years, the increase being more marked through the effects of the great flood years 1871, 1875 and 1877. It has been fully demonstrated that these floods, although they have occurred since the embankments were constructed on the western side of the Irrawaddy, did not arise from that cause. The dwellers in the neighbourhood of the Hline, however,

may not know that at Mandalay, at Thayetmyo and at Prome, far above the reach of the embankment works, the floods of the years mentioned were as abnormally high as in the delta, and therefore must have had origins independent of any delta works. But in the upper part of the Hline valley, and particularly in the region where the torrents we have been considering enter, there has been a gradual and persistent elevation of the flood level for a considerable period of time. It has affected the Irrawaddy equally with the Hline. It has increased since the embankment works have been developed, but was in progress before they began. It is due to the formation of a great bend in the Irrawaddy a few miles above Henzada, which has been taking place for the last 50 or 60 years, and which is now working towards a crisis. As is well known, such bends cause an elevation of the river surface above them, and a lowering below them, so that a double effect has been produced. The extent of this will presently be considered. It suffices now to note that the complaints of the people that the Hline surface has been raised, are well founded, though they are wrong in ascribing the Irrawaddy embankment as the cause of it.

The Thambyading bend.

134. Some projects for communication and navigation affecting the plains on both sides of the Hline have been from time to time brought forward. The need of roads reaching from the interior to the Irrawaddy was, before the construction of the railway, most urgently felt. When European Officers were placed in the district the head-quarters were formerly at Mengyee on the Irrawaddy; while the Deputy Commissioner and most of the district officials resided at Myanoung or Henzada. In the dry weather there is no difficulty in getting across from the river bank to the cultivated interior lands, nor is there much in the rains by boat, as several creeks open into the flooded land from the large river, and boats can go some distance up the streams in the rains. But towards the beginning and end of the rains there is a period of weeks or months when the land is half flooded and neither boats nor beasts can cross. When Tharrawaddy was only accessible from the Irrawaddy this caused serious inconvenience. It was proposed to run a road from Tahpoon to Talokmoh, and one survey was made; another surveyed and levelled by the writer was proposed from Tahpoon to opposite Myanoung. Both were found impracticable; as embankments would be required from 12 to 20 feet high to rise above the flood level and would interfere with the flow of the inundation water which moves slowly southward. Levels have also been taken at other parts of this inundated land. Some of these are given in Plate VII. showing the formation of the country. There is a great fall from the Irrawaddy bank to the Hline banks, amounting to nearly 10 feet on the Tahpoon—Myanoung road, while at Sanyuay the fall is nearly 22 feet. (Fig. 8, Plate VII.) This last shows the preliminary levels of a cart track near which it is contemplated to carry a branch line of railway from the Prome and Rangoon Railway at Thongzai to Henzada. The project is now under consideration, and the writer has received orders to carry out the necessary surveys and designs. It is proposed to carry the line on an elevated trestle work a few feet above the highest flood levels. The flood line is irregular, sloping from the Irrawaddy towards the Hline, where some 14 feet of water were found on the banks in 1875 and 1877, and again sloping upwards from there towards Thongzai. The Thongzai portion would be embanked; the height of the work being nearly 20 feet for two miles and from 12 to 15 for another three. By carrying a straight line from Sanyuay to the nearest point on the Irrawaddy the distance can be reduced to 8 miles through the inundated land. The trestles are intended to be of ironwood posts resting in cast-iron shoes tied together by iron rods and buried beneath the surface; and carrying a rigid superstructure of teak and iron, where the rails would be laid on longitudinal girders. The railway is of metre gauge; and as there is no probability of heavy goods traffic, both lighter permanent way and lighter rolling stock than is used on the main line can be employed. The want of rapid communication with Rangoon is much felt; and unless it is decided

Communication between the Irrawaddy and the interior of Tharrawaddy.

Railway from Henzada to Thongzai.

to proceed with the reclamation of the entire Hline valley some such project must be seriously entertained.

Navigation of the Hline.

135. Proposals have been made for improving the navigation of the Hline. cross sections are given in Plate 5, p. 63, for this river in differents parts of its course. These were taken in 1868 and little variation has taken place in the capacity of the stream since, though considerable changes have occurred on individual sections through excavation of the banks. From these sections it is seen that the river increases considerably in capacity in its downward course, even when measured within the banks. At Minboo on the Tahpoon road, when it has received the Shoaylay and the Kantha streams it is 180 feet wide and in one part about 20 feet deep. There is a decided tendency to silt up here at present, which has been encouraged by fishermens' dams thrown across the channel as the river falls. At Shway-loung the river has received the drainage of a large portion of the plain land as well as the water from the several torrents flowing down by the Minboo. It has also received the first large branch from the Irrawaddy, the Teindau. This branch when measured in 1874 was 240 feet wide and 20 feet deep at its mouth. For the past 15 years the Irrawaddy entrance to this has been in course of silting up, and a long tongue of land has formed in front of it. It commences to flow when the river is at half flood. The Hline after receiving it is 338 feet wide, the depth of water in March 1868 was $7\frac{1}{4}$ feet and depth from edge of bank to bed $26\frac{1}{2}$ feet. Its sectional area was approximately 5400 square feet. From this part southwards it excavates its channel. At Sanyuay, just above the mouth of the Thongzai Choung, the Hline is 680 feet wide with a depth from bank to bed of 44 feet, and dry weather depth of 12 feet. The rise and fall of the tide is here about 3 feet. Its approximate area within its banks was then about 19,000 square feet. At Emg-ka-bore, above the town of Hline, its width was 523 feet, cross section about 22,000 square feet, and depth of water over 20 feet in the dry weather. The river though sinuous is navigable for large boats and steamers to the north of Sanyuay all the year round, but the immense spread of the inundation and the absence of cultivation cause it to be little required for navigation. The railway parallel to it now takes away most of the traffic which formerly sought it, and unless the plains on both sides are reclaimed and cultivated there can be no object in attempting to improve its channel. Precautions will however have to be taken when the regulation of the torrent streams is put in hand, as this will have a tendency to bring down the whole of the silt they carry into the Hline, where if allowed to deposit immediately it will cause serious obstruction to the channel. When once the protection is afforded from the Irrawaddy floods, and the Pegu Yoma torrents are dealt with, the problem will assume a new form and importance. It will also best be dealt with then, as the various changes carried out will suggest new methods of dealing and new requirements. In the meantime the writer would place upon record a protest against such a scheme as Colonel Stoddard proposes which is to cause "the waters of the Irrawaddy, supplemented by the discharges of the Nawing and Loothat choung" to "be permanently diverted into the Hline." The object of this proposal was "to make a *navigable canal which can be used throughout the dry season*, or about 6 feet deep, a portion of the cutting in the distance between the mouth of the Nawing and the 5th mile" being "very heavy, not less than 43 feet." This canal would require locks and head sluices to regulate the flow. As the whole of the district of the Hline valley where this river is not navigable in the dry season is within a few miles of the Railway or of the Irrawaddy, it would be inexpedient to carry out works of such a grand and expensive character, even if success could be ensured. The Nawing itself is a large torrent stream with a greater reception basin than any of those of the Pegu Yoma yet considered. Its width near its mouth is over 200 feet and depth over 20 feet, and large bodies of water rush down with extreme velocity and violence. One of the first projects for the redemption of the plain should be to embank the Nawing and keep it altogether

Colonel Stoddard's proposal for the navigation of the Hline.

excluded. Navigation is here altogether of secondary importance to protection and irrigation.

Great value of the Hline valley if reclaimed.

136. The Hline valley plains offer perhaps the richest reward for all money expended upon their thorough reclamation and improvement of all the projects under review. They now present the features of a lage swamp of some 1,200 square miles in extent covered by a characteristic and luxurious vegetation. Immense trees, none of which are useful for timber, and barely for firewood, rise from the surface of the inundation in flood and spread their branches and foliage over the whole area. An impenetrable under-growth of smaller trees, shrubs, climbers and grass extends over a large part of the land. The herbage is poor and scattered, forming small patches of meadows along the borders of swamps but is never touched by cattle (Kurz.) In the dry weather occasional glades of open ground under the trees are met with, especially near some of the lakes. These form the only useful part of the tract, affording a precarious and stinted subsistence to villages of fishermen, who live in houses high up on posts so as to stand above the surface of the waters. The land itself is excellent in quality, having generally the precise mixture of sand and clay in a loam that is most fertile for rice, the one great production of the Irrawaddy delta. Formerly a fringe of high land near the Irrawaddy was cultivated, and several towns and large villages remain, but the cultivation has been rendered impossible by the rising of the river surface referred to. The population of these places is large and anxious to find agricultural work. It happens also that on the eastern side the greater part of the cultivable land fringes the inundation, and has a larger population than is required for the areas available. There is thus, on the spot, a supply of labor available which will rush the ground once it is opened out. The people have followed the survey operations with the utmost interest, and have more than once marked out the portions they intend to cultivate. From the success of the western works a guarantee may be derived of the certain financial success of any on this side which can protect and reclaim the area. The proposals made for these works and the conditions on which success in an engineering sense depends, will best be considered after a general review of the progress made with the existing ones, and the condition of the river itself.

SECTION VI.

The Irrawaddy Embankment Works.

The Irrawaddy Embankment works.

137. The existing Embankment Works on the Irrawaddy present themselves for consideration under different aspects according to the nature of the problems discussed. The financial questions, or the drainage and reclamation of each plain affected will be best dealt with by taking each work separately. But such questions as have been raised with reference to the floods or variations of channel of the Irrawaddy river are better met by grouping together for consideration those parts of the works similarly affected. As the more general problems were the first to present themselves in the actual progress of the works, the precise details of each will be naturally led up to by a brief historial sketch of their development to their present form. Three distinct periods are marked out in which different views and practices have prevailed regarding these works. The first period was previous to 1862, when protective works were treated as only casual adjuncts to agriculture in the delta, and some light embankments were constructed by the people under the direction of the civil officers; the labor being mostly voluntary or unpaid for. A second period is defined by the systematic construction of the works on the principles and from the designs of Colonel Short R. E., from 1862 to 1868: when they were undertaken as works of primary importance to the welfare of one of the most important parts of the Province. And a third period is from 1869 to the present time (1879), when important modifications of Colonel Short's designs have been introduced, and a great, though desultory, progress has been made in their construction and development.

Three periods of progress.

First period. Condion of the country previous to 1862.

138. Some valuable indications of the state of the country on the right bank of the Irrawaddy previous to 1862 are to be found in a Gazetteer compiled from the notes of Captain Fitzroy R. A., Superintendent of the Pegu Survey, and his staff, and published by Colonel Edgcombe R. E. From Bandee opposite Pantanaw to the Nawoon entrance, the district was divided into two townships—the Donabyo and Henzada, the first containing 6 circles on the west of the Irrawaddy, the last 13 circles. The line of levels taken from the foot of the hills and passing right across the delta shows a great depression in the general surface of the ground, removed from the edges of the rivers or of the streams. It appears there were considerable areas of rice cultivation in the more elevated parts of the grounds, which depended, however, on the light protective embankments for their existence. In all the lower parts the flood waters lay through most of the rainy season; having found their way in, in ordinary floods, through the numerous openings in the banks, and the general flatness of the country causing the inundation to lie with very slight flow on the ground. In the more southern portion of the district this state of things still exists, but then it was general. The Gazetteer notes "Donabyo Township Bandee Circle. The tract of country comprised within these boundaries is low (and covered with grass and tree jungle) the greatest portion of which is inundated during the rains, in some places to a depth of from 4 to 8 feet." "Hnaygyo Circle" for the most part a level tract covered with grass and tree jungle and uncultivated waste submerged during the rains, there are, however, some cultivated tracts in the neighbourhood of villages." Similar descriptions are given of each of the other circles, Donabyo and Nyoungyoung having a somewhat larger share of rice cultivation. It is the same in the Henzada township, where, however, the influence of embankments is adverted to. Of the Anoukpet circle just south of Henzada it is stated "the ground is low, covered with grass and tree jungle and forms in the rains a swamp, and in the extreme southeast is some jungle land, the other portions of the circle consist of rice-fields which however would be inundated by the Irrawaddy overflow were it not for the Anoukpet bund." The Dooya circle had much tree jungle "with the above exception the whole

area of this circle is under cultivation, but the ground being low is only preserved from inundation by embankments." Other parts are described as being submerged generally 3 or 4 feet, with 7 or 8 feet in the hollow and depressed places.

Light protective embankments before 1862.

139. So far as can now be ascertained the protective works referred to ran from Henzada southwards. One, the Anoukpet, was about 1½ miles long, and somewhat heavier than the others. It was situated immediately south of Henzada. Other lighter works ran in front of Henzada and between that town and Zaloon. There seem to have been few great floods on record in earlier years of the British occupation of the country; but one in 1861 brought disaster to such works as existed and to the cultivation dependent upon them. Mr. Fennessy, first Executive Engineer of the larger Embankment Works, gives in his Report of 1st November 1865, an extract from a letter of Father Naude, a French Missionary resident near Henzada, dated 1st September 1861, to Colonel Phayre, Chief Commissioner of British Burma, regarding the breaching of the old Anoukpet Embankment.

Flood of 1861 Anoukpet embankment.

"In all directions here the people have been ruined by the floods, and everybody is in the greatest despair. The Burmese and Karens desire and even demand that you should issue an order, calling on every one who has suffered from the inundation, to subscribe one or two pieces of wood and two or three rupees to assist in building a strong embankment capable of resisting the force of the torrent next year. It is very important that you should take some means or other, for if you do not, the whole population will be obliged to leave *en masse* and abandon their old fields."

Second period. Colonel Short deputed to devise embankment works.

140. The work just mentioned was totally destroyed in 1861, and a new one built by the Public Works Department in the same year. The Government of India was at the same time addressed by the Local Government, and Colonel Short R. E,, an officer with great experience of embankments in Bengal, was deputed in 1862 to Burma "to examine the country and report on the subject of embanking the Irrawaddy." Colonel Short accompanied by Mr. Fennessy examined carefully the works already existing near Henzada, and proceeded to Myanoung and Kyangheen where other small works also existed. Some extracts from the old Gazetteer will be given showing the condition of the lower plains behind Myanoung in connection with the drainage question. At present it may be stated that this tract was similar to that behind Henzada and Donabyo in having rice cultivation on all the higher lands, while the lower were entirely submerged in ordinary flood years. The former were liable to inundation in high floods. Colonel Short considered the Patashin hill torrent to be the primary cause of the damage to the Myanoung plain. He found on the north side of this stream an embanked road passing from the hilly ground to Kyangheen and along the Irrawaddy front of that town. This had been built by the civil officers and gave beneficial results, though wanting in strength. He heard of an old protective work constructed under Burmese rule across the low ground to the south of the Patashin, which had formed the supposed old channel of the Irrawaddy, but no vestige remained of it. The Patashin is a hill torrent entering the Irrawaddy four miles north of Myanoung. Spurs of hills run down its side bringing high land to within 4 miles from the river. Its section at the entrance to the plain was 200 feet wide, with 30 feet depth from bank to bed. At its mouth Colonel Short found it 388 feet wide with a depth of 35½ feet in flood. To the south of Myanoung is a portion of rocky ground, mostly sandstone rising above the level of the plain, and Colonel Short designed the first portion of the embankment work to extend from the high ground on the right bank of the Patashin, stretching across the low land between that stream and the Irrawaddy, and turning southwards along the bank of this river, finally resting on the high land south of Myanoung. The detailed drawings in Plate IX give the features and dimensions of this important work.

141. The reasons determining the principles and details embodied in this embankment are best given in Colonel Short's own words.* "The highest flood levels at different localities were pointed out by parties desired by the Deputy Commisssioner to attend me, and it is interesting to note that the levels partially proved the correctness of the information furnished." "At each successive rise of the Irrawaddy, the hill drainage must have been held back until it rose and forced its passage through and over the bund, and passed down as a great inundating wave to the rear and west of Myanoung via the channel met with, and together with the light spill over the right bank of the Irrawaddy above Myanoung this column of water has from time immemorial swept over and desolated the low country more or less to the base of the low range of hills bounding the cultivable lands to the west, and extending southwards to the Bassein River." "A careful inspection of the line of country...together with the test applied by the levels, leave no doubt but that the key to the safety of the country is to be found in arresting the great inundating column between the Patashin river at Napadee (where it suddenly flows due north towards the Irrawaddy) and the high level on the right bank of the Irrawaddy, whereon stands the village of Malakagong. From the date of the construction of a permanent work as a great flank embankment, security to life and property will be ensured to south and west, and an area of at least 250 square miles which is now unproductive will be capable of being richly cultivated; not to mention the increased facility that will be afforded to drain the area by the natural channels into the Bassein river to the south, whereby the salubrity of the interior will be greatly improved."

Principles and details of Colonel Short's plans.

142. "Protective works constructed on proper principles must not interfere materially with the waterway, nor be liable to be taken in flank, they must be raised well above the highest recorded flood level, and be of a section more than sufficient to withstand the greatest shock; and above all retired from the rivers bank in proportion to the known features thereof and the erosion recorded during a period of from 10 to 20 years, and with reference also to the set of the river's current, which has to be first studied in order to ascertain the natural formations which cause the floods to be diverted at particular localities." These requirements he hoped were fully met by the line of embankment proposed. He also dwells on the necessity of leaving plenty of room for the flood waters to expand in at the junction of the Patashin with the Irrawaddy.

Requirements of protective works.

143. On examining the original plans signed by Colonel Short the line of the embankments is found to consist of bold sweeping curves which strike across the country without following the sinuosities of the Patashin. The first portion of the work flanks this stream, the nearest points of approach being 600 feet, the length 2 miles 384 feet, the crest of the embankment 4 feet broad, and 4 feet above highest flood level and slopes of 3 to 1 and 2 to 1. A second part strikes across the low land at a distance in places of more than half a mile from the river. Here the flood mark was 10·20 feet above the ground. The total length of this part was 1 mile 1,920 feet; and for a length of 3,840 feet in centre its crest was raised 6 feet above the highest flood, with top breadth of 10 feet, and slopes of 4 to 1 and 3 to 1. On reaching the Irrawaddy a minimum distance of 500 feet from the edge was chosen, careful enquiry having shown that little or no erosion had taken place there; and the remainder of the work which, in all, was 7 miles and 1,954 feet, was raised 4½ feet above flood level, and 5 feet broad, with slopes of 3 to 1 on the exterior and 2½ to 1 on the interior.

The Myanoung Flank embankment.

144. The town of Myanoung was left outside the embankment, apparently as Colonel Short had reason to believe that it rarely suffered from the Irrawaddy floods. The line of the work is here retired over ¼ of a mile from the bank in one part, and

Embankment at Myanoung Town.

nearly as much for a mile in length. The bank and the town as they are shown in Colonel Short's plans have been copied in dotted lines on Plate IX. The works were carried out according to his designs in the year 1863-64; sluices being provided through the embankment to take away any spill from the Irrawaddy or rainfall which might accumulate in the low land between the embankment and the river. These were of brick masonry, originally with wooden sliding doors; one sluice, that placed in the lowest ground between the Patashin and the Irrawaddy, was of large size, having three separate apertures of 7½ feet in height by 4 feet wide. The doors lifted by a capstan and chain fixed above. The intention in providing this large sluice draining inwards was to carry off through the country any light spill from the Patashin, which in dry seasons would also be useful for irrigation. Experience proved that the extent of the spill from both the Patashin and Irrawaddy had been misconceived, for when it does pass over the bank the water accumulates so quickly that the velocity in passing it through any of these sluices would be more than the brickwork could bear. Mr. Bennett, Executive Engineer in charge of the works during the 1868 flood, found it necessary to close most of these sluices permanently, and take great precautions to prevent the whole being carried away. Small iron gates have since been inserted; and it has been found advisable never to allow these to be open with more than 3 square feet aperture at any time.

Sluices.

145. The remainder of the works executed up to the close of 1868 was carried out in accordance with Colonel Short's designs and principles. A new embankment was planned and executed by Mr. Fennessy during 1864-66 for Kyangheen. It is somewhat of elongated horse-shoe form lying between the Irrawaddy and the northern bank of the Patashin. Its Irrawaddy branch is about 4½ miles long. It runs through the town of Kyangheen, and was originally designed at a minimum distance of 500 feet from the bank. On the Patashin side it stands mostly far from the stream leaving a free expanse of 1¼ miles between itself and the Myanoung Flank embankment. Except on about 990 feet in length of this work, in all 9 miles long, its crest was raised 4 feet above high flood mark, it was 5 feet wide at top, and the slopes were 2½ to 1 and 2 to 1. The 990 feet of lowest ground had the work raised 5 feet above high water mark, where this stood above 8 feet on the ground. The purpose of this work was to serve as a road for Kyangheen town; to protect the cultivated area already existing there, some 2,000 acres, and to reclaim nearly 2,000 more then lying yearly under water and uncultivable. It was intended to entirely exclude the hill water from this tract, but some amount of this drainage still found its way in after the work was finished; and it was not till 1870, when a small cross embankment was carried from some elevated ground projecting inside the embanked area to the Patashin embankment at about one mile from its extremity, that protection was afforded. Then it was found that 3 self acting drainage sluices of a pattern designed by Colonel Horseley, Madras Engineers, and recommended by Colonel Stoddard, sufficed to keep the interior free from water. The sluice doors are of horizontal parallel stripes of iron planed and fitted edge to edge, and hinged together on the outside. They are attached to the outer end of a brick sluice, with waterway of 5 feet in height by 2½ feet wide. The gates are hung with their upper ends firmly bolted to a wooden fixed frame work, slightly inclined inwards at top. The slightest difference of pressure of the inner over the outer water opens them, and allows free exit to the drainage when the river falls. When it rises the outer pressure closes them. They are simple, cheap and efficient, and have given no trouble of any kind. The hinges are of brass, and galvanic action is prevented by a thick coating of tar between the metals. Drawings of these sluices are given in Plate IX.

Kyangheen Embankment.

Small cross Embankment.

Self acting sluice.

146. Mr. Fennessy carried a small road over the elevated sandstone ground south of Myanoung to connect the first or Flank Myanoung embankment with succeeding works. This was done in 1864. It brought the total length of line to above 10½ miles. Colonel Short's complete proposals were to exclude the Irrawaddy water wholly from the Myanoung and Henzada plains on its right bank, and also to close the entrance to the Bassein river. At that time the entrance had long been closing of itself. There was formerly only one, the Nawoon or southern entrance; which, owing to a series of changes occurring in the river channel at that part had long been closing up. The central fact of these changes was the formation of a large bend in the river, the point of the bend advancing due west, while the two sides of the bend continued to approach. At the particular stage of the change in progress at the time Colonel Short's designs were conceived a large sandbank had formed in front of the opening to the Nawoon, and there had been a continual deposit of sand and finer silt within the upper portion of the channel itself, which threatened to close it finally. It is said to have closed for dry weather navigation in the year 1829 and the late Mr. Login, an experienced Civil Engineer, whose name has been more than once referred to, was deputed by the Government soon after the war of 1854 to devise means for opening out the channel and keeping it open all the year round. No trace of Mr. Login's report can now be found; but some of his notes and observations on the river are published in the Edinburgh Philosophical Journal; and he is often quoted as an authority connected with the Irrawaddy. From other sources it apears Mr. Login carefully examined into the project for opening the Nawoon, but came to the conlusion that all such projects were impracticable or inexpedient, while such enormous changes were in progress as were then developed on the great bend. There can be no question as to the soundness of his views. The Nawoon entrance has continued closing year by year, large sandbanks advancing further and further down its channel. Cross sections taken at 1¼ miles from its mouth at different periods by Mr. Fennessy and the writer, show the state to which this channel, once over 50 feet deep, has arrived. (See Plate XIX.) Even in 1865 it was quite possible to close the entrance. Mr. Fennessy proposed doing so by a masonry anicut or weir. This would have been expensive, and probably a simple earthern dam with rows of sheet piles on either side to prevent percolation underneath would have been found sufficient. Events have, however, changed the design of the works, and the consideration of detailed plans for closing this entrance may be left till they are required.

High level Road.

Continuation of Myanoung embankment.

Nawoon river entrance.

Mr. Login, C. E. Report on the Irrawaddy.

147. The most important of these events was the rapid advance of the point of the bend westward at Thambyading together with the opening out of a new channel there. The old Gazetteer thus refers to the Thambyading Choung, now the only available entrance to the Nawoon river. "The Kanyeng (or Okpho) Choung has its source in the Aracan mountains ... it empties itself into the Bassein river at Tsengong, sending off a branch called the Thambyading Choung into the Irrawaddy river." "The Thambyading Choung is only 2 miles long, it is not navigable for boats in the dry weather." This indicates that previous to 1862 or 1863 the Thambyading discharged water from the Okpho into the Irrawaddy. The writer endeavoured to learn all that could be told him in the neighbourhood in 1869 regarding the changes at Thambyading; and in a report dated 9th July 1869 he was able to state as follows:—"The Thambyading river opens from the Irrawaddy about 5 miles north of the Nawoon. Formerly it was an insignificant stream, and the opening in the bank was several miles to the north east of the present position. The alteration is through the west bank of the Irrawaddy having for many years past been carried away at this part, with a change of the whole course

The Thambyading Bend.

The Thambyading river.

of the river. The "Thoogyee," or native revenue officer of Thambyading, who procured the information for me from the oldest residents, all of whom spoke from personal knowledge, says that forty-five years ago the Irrawaddy first manifested a decided tendency westward at this particular point. Since then it has moved three Burmese or six English miles; and within the last ten years it has moved over three English miles. The Thambyading has been gradually enlarging; and in 1863 for the first time opened for the passage of boats in the dry weather. The enlargement of the channel has since been more rapid."

Enlargement of Thambyading river entrance.

148. "I measured it on the 19th May 1869, taking a cross section on the contemplated line of embankment. The width was 276 feet, the greatest depth 54½ feet. In 1865 it was measured by Mr. Fennessy in the same place. The width was then 170 feet and the greatest depth 42½ feet. While I was measuring, the banks on both sides were falling and the channel enlarging. The Irrawaddy was rapidly rising. Almost the whole village of Thambyading was in course of removal, and a clear space of five or six hundred feet was left on the bank of the Irrawaddy in anticipation of so much of it being carried away. Last year about 600 feet of this bank disappeared. In April 1865 the distance of the embankment line from the Irrawaddy bank was 4,800 feet. In May 1869 the length measured was only 1,603 feet. The bank is at present falling daily. Everything indicates that the Irrawaddy is making a decided set towards the sources of the Bassein river, and has been doing so for a long time. It at present promises to continue, but what the final results will be it is impossible to say."

Proposals to close all the entrances to the Bassein river.

149. These extracts somewhat anticipate the narrative of the embankment progress; but show the grave difficulty that had to be overcome in carrying out Colonel Short's views. The closing of the Nawoon would have been easy; that of the Thambyading difficult, though practicable, in 1865. This was an integral part of the embankment scheme as then devised, and Mr. Fennessy laid out and projected a line of embankment from the end of the high level road mentioned to Henzada; both the Nawoon and the Thambyading, as well as the Noukmee, being intended to be closed. This last stream is a slow running drainage channel debouching into the Irrawaddy 3¼ miles above the Thambyading entrance. No difficulty was likely to arise from doing this, as it is connected by branches to other drainage channels which can carry off its surplus water. The serious nature of the difficulty appears to have been fully present to Mr. Fennessy's mind, for while he has followed Colonel Short's minimum of 500 or 600 feet as the closest approach of the line to the river bank in its most secure parts, he has removed it to a vastly increased distance in some of its southern parts. Measured on the original plans the distance at Noukmee the 47th mile is about 3200 feet; at the 49th mile, (including the flank embankment,) it is 4200 feet; at Thambyading as stated above 4800 feet; and at the 52nd mile 6800 feet. Its total length was to be 65 miles 2780 feet; and for the whole of the last 16 miles the work is only in one place within half a mile of the river, while it is generally at a greater distance.

Distances of embankment from river edge.

Disadvantages of retired embankments.

Natural embankment of the river.

150. This removal of the work to a great distance from the river edge brings with it in such a river as the Irrawaddy two disadvantages. The banks have been formed by the deposition of silt from the repeated overflows of the river. The silt being more thickly laid on the ground nearest the edge raises this to a greater degree than the interior lands. The raised surface thus takes a gradual slope, constituting a natural embankment. The cross sections of levels given on the several plates (IX. to XVIII.) show that this formation is met with in every part of the

country where the embankment lines run. There is, at the outer edge of the bank, a narrow strip of land, more or less broad according to the length of time the flood waters have had free play over it, which is raised above the level of ordinary floods, and which is rarely topped more than 3 or 4 feet by the very highest floods. An embankment carried upon this would only have a depth of 3 or 4 feet of water against it in the most extreme flood. But on receding from this edge the ground falls; sometimes very rapidly. On an average it appears about 8 or 10 feet in the first half mile, though it is sometimes more, while occasionally the bank of an abandoned creek may be found well raised above the lower level and offering a suitable site for embankment works. No well defined record exists of the flood which furnished the marks by which Colonel Short and Mr. Fennessy determined the height of the embankment designed by them; but from their statements it appears to have been very little over what would now be called an ordinary flood, scarsely rising above the crest of the bank. It was certainly much below such floods as those of 1871, 1875 and 1877 and was lower than the flood of 1868. But even with this small flood, the minimum retirement brought with it a depth of water on the site of the embankment averaging over 5 feet, while several miles are marked with depths of water of 7 or 8 feet. A few miles where the ground was more favourable particularly the 30th to the 34th have a smaller water height; but in the greatly retired parts of the line north of the Thambyading the water is shown to stand over 10 feet on the site; while south of it there are depths of 14, 16, and 18 feet. From the Nawoon southwards the line runs on an old bank for about 3 miles, with only a few feet of water in flood; but further south there are again depths of 10, 12, and 14 feet; while for the last 2 or 3 miles of the work, just where it lies behind Henzada the depths of water shown at the bund site are from 8 to 10½ feet.

151. Mr. Fennessy proposed a uniform section for the work. The crest was 5 feet above flood level and 5 feet broad. The slopes were 2½ to 1 on the outside, and 2 to 1 on the inside. A comparison of this section for different heights of work shows that the cubic contents of the embankment increase nearly as the square of the height. The rate per 100 cubic feet also increases with the height. Plain earthwork, when the earth is dug and carried to within 100 feet can be got done for 8 annas per 100 cubic feet. But 10 and 12 annas and 1 Rupee have to be given as the lead gets longer, and the height rises above 8 feet. The retirement of the embankment from the river's edge thus brings with it an excessively enhanced cost of the work. It also diminishes its safety. Whatever precautions are taken, earthwork is never absolutely safe. So many materials are mingled in the composition of the ground, sometimes heterogeneously, that there is no uniform resistance to pressure, or to changes of shape such as inevitably occur in subsidence. And some materials like sand are readily pervious to water; others to white-ants, rats and other vermine. Often no indications are apparent of deterioration from this cause either in the elevated works, or in the natural ground, and the dangers are immensely increased when the pressure of water is great, as it then readily finds out the weak spots, while the opportunities of remedying them are lessened.

Cross Section of Myanoung embankment.

Sources of danger to earthwork

152. Another disadvantage of the great retirement of the work was made manifest in the flood of 1868. The work as designed and as figured in Plates IX &c., was sanctioned in 1866, and, with the exception of the portion between the 44¼ and 50½ miles, was executed principally by Mr. Bennett, C. E., according to Mr. Fennessy's plans in 1867 and 1868. The flood of the latter year rose on the unfinished work. The continuous portion of this from the first to the 44¼th mile withstood the test well, though much anxiety was caused by the unconsolidated state of the earth, and by the sluices. These difficulties were overcome. The flood rose above the original datum points; but nowhere surmounted the work. Mr. Bennett and Supervisor Henry succeeded in stopping all leaks and saving the work when it threatened to go. The flood heights were

The flood of 1868 and the embankment works.

noted, and permanent bench marks afterwards built. The towns of Myanoung and Kanoung were inundated. It was clear that the Irrawaddy flood rise was greater than apprehended by Colonel Short, and the inconvenience caused to these towns more felt than he anticipated. The Jail and other Government buildings were under water. Colonel Fraser, then Chief Engineer, Colonel Oliphant, and Mr. Bennett, in consultation proposed marginal embankments in front of these towns to obviate such inconvenience for the future. Mr. Bennett commenced these works, which were completed by the writer in 1869.

Marginal enbankment for towns.

153. The southern portion of the embankment did not fare so well as the northern. The part between the Nawoon and the Thambyading was disconnected from all support, and the water stood at equal heights on both sides of it; but as it stood in the midst of swamps no great harm was done. The lower portion south of the Nawoon was breached in two or three places. The work was not quite finished and was unconsolidated. Some sluice work of a temporary nature was left in the embankment, and the water found its way through in one place. At another, a dam thrown over a large creek, the Pyeema Choung, gave way, carrying the work with it. One or two lives were lost, and cultivation was damaged. The work had not been joined on to the Anoukpet embankment; which, raised and strengthened in 1864, rendered very efficient service then and since. It was fortunate for Henzada town that the work was not completed and sufficiently strong. Otherwise from 10 to 12 feet of water would have been shut in to the lower part of the town, and particularly at the neighbourhood where this report is written, destroying houses, Government buildings, and possibly life. What was a convenience for Myanoung and Kanoung was an absolute necessity for Henzada. A marginal embankment was indispensable. Mr. Bennett was in course of projecting one in accordance with the result of the consultation before mentioned when the writer took over the works and completed it.

Embankment near Henzada.

154. The three marginal embankments were finished in 1869. They are shown together with the other works on the detailed plans in Plates IX. to XVIII. They were only raised 1½ to 2 feet above the flood level of 1868. They followed pretty closely the edge of the bank, but in the towns themselves this position was determined by the street along which they ran. The consequences of the construction of these light embankments have been more important than was at first anticipated. The question was put:—If light marginal embankments can be made to serve as outworks or protections for the larger embankments, why not make them serve instead of them? If the smaller works can keep the flood waters from a town, at the same time keeping it from the bigger ones, it seemed expedient to dispense with the latter, and only recur to retired lines when erosion seemed threatening the bank. It was determined to take advantage of the high ground on the edge of the river wherever it was possible to do so, keeping just a sufficient distance away from the extreme edge, always over 100 feet, to prevent damage from casual slips of the soft alluvial soil. The sweeping lines and bold curves of Colonel Short's and Mr. Fennessy's projects were abandoned, when these necessitated leaving the high land, and though it has been found practicable to render the alignment equally pleasing to the eye with smaller curves, the first object in laying out the works has been to economize the cost and increase the strength and safety of the embankments, by fixing the line on that part of the natural sloping bank, where these purposes would be best attained.

Advantages of marginal embankments.

155. It was only gradually this decision was come to. When the question of embanking both sides of the Irrawaddy from Talokmoh to Yandoon was discussed in 1868, the expediency of leaving open both channels of the Nawoon river was recognized both on account of their utility for navigation, and because the rapidly increasing size of the Thambyading offered an exit for a

Determination to leave open the Bassein river entrance.

portion of the additional water to be thrown into the Irrawaddy, at the same time that the difficulty of closing the entrance increased. It was then settled by the orders of Government that the Nawoon connections with the Irrawaddy were to be left open as long as they were useful. This brought with it a complete change from the designs of Colonel Short. The one great embankment on the right bank of the Irrawaddy was to be broken into two, and the left bank of the Nawoon was to be embanked in continuation of the lower part of the work then constructed, thus constituting two separate works, the Myanoung and the Henzada embankments, protecting what has been called the Myanoung and Henzada plains.

Changes in design of embankment.

156. In accordance with these views the first instalment of the Leymyethna Embankment was designed. It extends from Nawoon-Wa where Project No. 6 of Mr. Fennessy crosses the Nawoon entrance about a mile from the Irrawaddy, to opposite the town of Leymyethna, which gives its name to the section. When first laid out in 1869 by the writer it was intended to use the work as a road as well as an embankment, and short straight lines running from one bend of the river to another were joined by large sweeping curves; the distance from Nawoon-Wa to Leymyethna being originally 22⅓ miles. The minimum distance from the line to the edge of the bank was chosen at 350 feet. The first eight miles were executed according to these designs, when a further study of the question, after a careful examination of the country, with more experience of the requirements, suggested the course above described, of following as far as practicable the windings of the river on the high edge of the bank where there was no cutting away, or where the process of deposit was observable to be in operation. The realignment of the work lengthened it to 25½ miles. This plan has been adopted throughout the whole length of the Nawoon River Embankment; and has resulted in a maximum of safety with a minimum of cost. In carrying out these views, which received the approval of the Chief Engineer Colonel Fraser and the Local Government, the writer was ably assisted by Mr. H. J. Richard, now Executive Engineer, who subsequently aligned and levelled 55 of the remaining miles of this work sanctioned; which, when executed, will bring the Nawoon Embankment to the opening of the Taboo choung with a total length of 80 miles. At present only 70½ are completed continuously. Wherever the high margin of land was sufficiently broad to permit it, the work has been kept at a mean distance of 300 to 400 feet from the rivers' edge, but in some cases it has been brought closer with advantage, and every effort was made to follow the higher ground where this could be done with safety. In a few instances, particularly from the 40th to the 44th mile; and from the 55th to the 59th mile, the work is obliged to cut across low ground to save following a circuitous bend. In all the cases of these short cuts the water lies deep on the ground, and as will subsequently be shown the embankment there has caused much anxiety. The first four miles of the Nawoon Embankment were executed in 1869; when operations were suspended till 1871. In this year and in 1872, the first 25½ miles were completed, in 1872-73, the work was carried to the 40th mile; in 1874-75 to the 54th mile; and in 1875-76 it was extended to the 70½th mile; two or three miles of unconnected work lying beyond this point. All subsequent operations have been confined to raising and strengthening the work; owing to the elevation of the river surface. No changes or revision of the alignment of the embankment have been necessitated through erosions of the bank. The details of this work, with its final extension, and the changes brought about on the Nawoon river will be noticed in the next part of this Report.

Henzada Embankment. Nawoon river branch.

157. Simultaneously with the surveys for the Nawoon Embankment, others for a continuation of the Irrawaddy Embankment southwards from Henzada were made. All work was suspended *sine die* on the main Irrawaddy embankment between the 44¼th and 50½th miles, in 1869, as surveys made showed that the erosion of the great bend was tending to attack the site of the

Henzada Embankment. Irrawaddy branch.

work in that part. A new commencement was then made from the Nawoon southwards. The Henzada marginal embankment was connected to the old main one about the 4th mile from the Nawoon, and was itself connected with the principal embankment. It was further connected with the Anoukpet Embankment at its south end. Cross embankments connected both with the large work behind the town. All of these were executed in 1869. It may be here mentioned that the marginal embankment has kept out the floods of 1871, 1875, and 1877 without breaching; and, though local erosion of the banks has necessitated the removing of an exposed portion of the work to a road further retired from the river, the cost of doing this has been small. This will be further considered in connection with the lateral variations of the river, and the methods proposed for dealing with them. As the town of Henzada was completely surrounded by embankment on all sides, it became necessary to provide a system of drainage for it. This was accomplished by a series of surface drains carried along the road sides, always open at top; the principal ones being of masonry. The fall of the ground being always inland, the greater part of the drainage was collected into the bed of an old stream, and passed through the rear embankment by a double barrelled sluice, with waterways of 7 by $2\frac{1}{4}$ feet. Other sluices 6 in number were added at different points of the embankment. These consist of iron pipes 2 feet internal diameter laid well into the solid ground with socket joints; the higher end of the pipe being closed with an ordinary iron sliding block worked by screws. These are shown in Plate XIV. They suffice to carry away all rainfall, and if ever the marginal embankment breaches in flood are intended to be closed; the alternative will then be presented of swamping Henzada, a town of over 20,000 inhabitants, or of cutting through the rear embankment. The latter is to be preferred; and full authority should be given beforehand to the engineer or civil authority in charge to act at once if such a contingency occurs, as the Government and other property may be seriously damaged by delay.

Drainage of Henzada town.

Danger to Henzada from rear embankment.

158. The Zaloon section extends through the large villages of Toungbotaya and Doungyee, to the town of Zaloon, the length being nearly 14 miles. Cross sections of the bank taken at every mile or two showed that generally the slope of the ground is more gentle than further north, as it seems to have been exposed for a longer time to the undisturbed action of the river. In some parts the fall from the edge of the bank inward is only 4 to 5 feet in the first half mile. In others, however, it is 7 or 8 feet. The work was accordingly laid out with a minimum distance of 200 feet from the river edge increased to 400 or 500 feet when slight erosion was manifest, and in the actual construction of the work in 1872, when it was found that a somewhat extensive erosion was in progress at Toungbotaya and Doungyee, further retirements were made, in the former case to the extent of 500 feet for about one mile, in the latter of 1,200 to 1,300 feet for a mile and a half. The cutting of the bank had been at the rate of nearly 100 feet yearly for three years. Experience has proved that the former distance was more than sufficient; the latter bringing the work into very low and sandy ground which has caused great anxiety and a breach in the embankment in 1877. The river ceased cutting away at these particular places soon after the work was completed; transferring its local action to other parts.

Continuation of embankment to Zaloon.

159. The further extension of the Irrawaddy main embankment from Zaloon to Donabyoo was carried out in the years 1873-74-75. Alternative lines offered themselves; one, that actually chosen, and which presents precisely similar features to those of the Zaloon line; another shorter and straighter line, well inland, following what appears to be an old bank of the river, marking out a former variation of its channel in this part. In front of Donabyoo town, the embankment acts as a Strand Road. It is on or near the edge of the bank, and no difficulty of any

Extension to Donabyo.

kind has as yet been experienced from erosion. This portion of the work is very light, and can be moved, if necessary, at a small cost. An extension of the work to opposite Pantanaw has just been submitted for sanction. It was originally levelled in part, and half of it, as far as Setkaw, designed and submitted to the Local Government in 1873; but the Government preferred pressing on the extension of the Nawoon embankment at that time, and sanction was obtained instead to the last section completed of that work.

Alignment of embankment.

160. The alignment of all these parts of the embankment is accurately given on the plans. It forms the most important feature of these works, as on it depends the first cost and subsequent security and success of the embankments. Errors in height or form of section can easily be rectified if the line is well chosen, but nothing short of a re-construction of the work can compensate for an ill chosen line. As, in a few cases, it has been necessary to remove or re-align small portions of the Irrawaddy branch of the Henzada embankment constructed since 1868 owing to the erosions of the river, it is desirable to examine what the result of the alternative courses would have been; 1st, of following Colonel Short's principles; 2nd, of constructing protective works on the river to divert the current, as advocated by Colonel Stoddard and others; 3rd, of allowing the river free play over the bank until the erosion ceases, during which time it may inundate a part of the low country with the water but will raise a new elevated bank to flood level with the silt.

Comparison of different principles.

Alteration of all embankment works to a uniform section.

161. Before discussing these points, it should be noted that the section of all the embankment works has been changed to a uniform shape. Colonel Short gave different heights, different widths of crest, varying from 4 to 6 feet in the former, and 5 to 10 feet in the latter to his embankment, and increased slopes, according as the work the embankment had to perform increased. In this he was followed by Mr. Fennessy, and at first by the writer. While the marks of highest flood were doubtful, it was requisite to take unusual precautions to keep the greater works above water and to prevent subsidence. The crest was found inconveniently narrow in practice and a top width of 14 feet was decided on to permit the embankment to serve as roads for light traffic. The floods of 1868, of 1871, and of 1875 each brought with them alterations in height to the existing Irrawaddy line of embankment, and it was found expedient to propose raising the crest in each case to a height of 3 feet above the carefully recorded flood marks. Little alteration was made in the height owing to the flood of 1877 to those works, but on the Nawoon line the floods of 1875, 1876 and 1877 have each brought alterations, the minimum height being now on this side two feet above the highest flood rise of 1877. The slopes of $2\frac{1}{2}$ to 1 and 2 to 1 are retained for all ordinarily good soils, while light sandy soil, or sliding clay receive greater slopes to provide the requisite strength. Premising that these changes, which will be again referred to in connection with the flood rises, have been made, a comparison can be made on point of cost between the embankment lines where the different distances of retirement from the rivers edge have been made.

Comparison of cost of different styles of embankment works.

162. Leaving out all accessory expenses and subordinate works, such as payments for land, drainage sluices, bungalows &c., the cost of the Kyangheen Embankment up to the end of the financial year 1877-78 is as follows :—

Kyangheen Embankment 9 miles long.		
Original cost previous to 1868	Rs.	63,828
Cost of raising and strengthening owing to 1875 flood Rs. 38,565 of which were spent in 1877-78	„	28,870
		92,698
Total ultimate cost for 9 miles ... ... about Rs. 100,000		
or per mile	„	11,111

The cost of the various parts of the Myanoung Embankment are :—

Flank Embankment 1st seven miles, with additions previous to 1875,	Rs. 1,21,344
Myanoung Embankment Project No. 6 about 38 miles.	
Expended on original construction	„ 5,53,763
	Rs. 6,75,107

Raising and strengthening subsequent to 1875.

Sanctioned Rs. 90,904.	
Expended in 1877-78 ...	71,192
Total	7,46,299

163. The original cost per mile of the Flank Embankment was thus 17,335 Rs. and of Project No. 6 about 14,573 Rs. The average cost of the whole when completed as now designed will be almost exactly 17,000 Rs. per mile.

Henzada Embankment.

	Rs.	Rate per mile.
Last 10 miles of Project No. 6 original cost	2,24,409	22,441
Zaloon section original cost 14 miles	93,777	6,697
Donabyoo „ „ „ 24 „	1,37,064	5,708
Leymyethna „ „ „ 25½ „	2,12,037	8,320
Ngathaingyoung „ „ „ 25 „	2,02,918	8,116
Taboo „ „ „ 19 completed	1,22,399	6,860

Raising and strengthening some of the above works has cost to end of 1877-78.

Zaloon section 14 miles	15,091	1,780
Henzada (including marginal Embankment) and Anoukpet 13 miles	24,517	1,917
Leymyethna section	57,770	2,266
Ngathain-gyoung „	81,319	3,253

164. The last averages added to the former bring the cost per mile of the Zaloon section to Rs. 8,477, of the Leymyethna to Rs. 10,586, and of the Ngathaingyoung to Rs. 11,369. It is to be observed that the last two feel the effect of the raising of the Nawoon river surface the most severely, and the cost of strengthening these works arises solely from this cause. The other averages are the true costs of the respective works. On the Nawoon side a set off should be made for the increased length of the works owing to following the rivers curves; but this is slight, amounting on the whole length to less than 3 per cent. The Zaloon and Donabyoo sections are as straight as can be desired. These average, taken together, less than Rs. 6,500 per mile; the whole of the main works constructed since 1868, averaging on a length of 110 miles less than Rs. 8,400 per mile. The contrast between the cost of the Zaloon and Donabyoo sections and that of the original Henzada one is the more noticeable, as they are made in precisely the same country; and the difference is solely ascribable to the degree of retirement from the edge of the river. The difference would be still greater, if the larger work had been raised and strengthened after the 1875 flood like the other works. This has not been done for the last 6 miles of it, which are protected by the marginal embankment. The cost of this work was, for over 6 miles in length, Rs. 37,758, nearly the same average as the Zaloon and Donabyoo works. The Myanoung marginal work cost Rs. 8,487 for 2 miles or about Rs. 4,250 per mile. For the Kanoung work it was Rs. 13,327 for 6¼ miles, an average of Rs. 2,130 per mile.

Necessity of discussing the lateral changes of the river channel.

165. The purpose of bringing this question of cost and comparative safety and efficiency of these different systems of embankment alignment prominently forward is to enable a determination to be arrived at with regard to future works of the same kind in the Irrawaddy delta, and particularly the proposed Tharrawaddy embankment on the left bank of the river, to extend from Talokmoh to Yandoon. Surveys and levels have been made for the work along the bank, both longitudinal and across. They are given in the top parts of Plates IX to XVIII. The line has been here chosen often approaching within 100 feet from the edge, so as to permit the highest ground to be used, especially

in the northern half of the work. Further south the high level margin is broader and the work is more retired. Before this choice can be finally justified, it is necessary to point out that there are several modifying circumstances which have to be considered. The line chosen by Colonel Short has much to be said in its favor, and it is to be mentioned that both the Myanoung marginal embankment has been removed for half its length owing to erosions, and about half a mile of the Henzada marginal work has also been moved. The Kanoung embankment is now threatened in one part; and portions of the Zaloon and of the Donabyoo embankments have been removed. It thus becomes a matter for consideration which has more than once been raised :—Is it not better to at once incur greater first cost by greater general retirement of line, than to have these repeated removals ? This can be answered only by examining the nature of the changes in the river which necessitate these retirements; as without such changes in the channel there could be no objection to the work approaching the most extreme edge of the river.

SECTION VII.

Lateral variations of the Irrawaddy Channel in the delta.

166. Different surveys have been made of the portion of the Irrawaddy channel between Talokmoh and Yandoon; the earliest accurate one of the banks by theodolite traverse having been executed by Colonel W. S. Trevor V. C., R. E., (then Lieutenant Trevor, and now Chief Engineer of this Province) soon after the British occupation in 1854. The large scale maps have been lost, or lost sight of; but the results are given on a scale of 4 miles to an inch in Captain Fitzroy's maps and on 2 miles to an inch in his Gazetteer. The work occupied two or three seasons from about 1855 to 1857.

First accurate Survey of Irrawaddy Channel.

167. Partial surveys of portions of the channel and the banks have frequently been made in connection with the embankment works. Mr. Fennessy had a part of the Thambyading bend surveyed in 1864 or 1865. The writer caused compass surveys of the channel to be made in 1873 from Myanoung to Henzada and on several occasions before and since on different shorter portions. In 1877 Mr. Smart, Assistant Engineer, assisted by Mr. Rumsby, was deputed by the writer to take a complete theodolite survey from Saiktha and Talokmoh to Yandoon and Pantanaw, to show the whole features of the channel, with the more prominent details of the embankment works, in connection with the investigations being conducted upon the river. The outlines of both banks and of the embankment works were filled in from several surveys made by different parties. The sandbanks were figured in from compass surveys made at lowest water in February, March and April 1877. A series of cross sections of the channel between the extreme banks was made simultaneously by an experienced surveyor, Overseer Shere Mahomed. Mr. Smart also measured the depths of water in the channel when the water was nearest its lowest, connecting them with the survey stations on the banks, and with the readings of the gauges at all the recording stations.

Subsequent Surveys.

168. The results of these observations and surveys are given in the series of Plates numbered from IX to XVIII, and the more important details connected with the river and the Irrawaddy embankment works are also figured there. A block plan of the river channel in Plate VIII, serves as a key to connect the separate sheets.

Large and small scale plans attached.

169. The horizontal or lateral variations of the river channel call for the first notice. On comparing the plan of the river with the numerous cross sections it will be found that the river consists always of one large and well defined channel, with generally a broad space occupied by islands, sand banks and smaller channels to one or other side of it. In only one or two cases do any of the smaller channels approach in size to the principal one. The entire width of the stream in high floods, including the main and minor channels, and the spaces above the islands is occupied by flowing water, these forming the complete flood channel of the river. The high banks marking out the extreme limit of these minor channels and sand banks are the bounds of the river chan-

Lateral variations of the river channel.

Distinction of Main and Minor channels.

nel at present; and define the variations of its course within the most recent geological period. These banks containing the complete flood channel have been called the permanent banks, to discriminate them from the more recent formations, which are generally presented to the traveller on the main channel of the river. On these permanent banks the existing works on the west side of the river stand, and the projected one on the east side has been traced.

Complete flood channel.

Permanent banks.

170. Following the course of the river from Saiktha downwards it is seen that on once leaving the rock-confined channel at that place, the complete flood channel occupies a width of from four to six miles almost the whole way to the great Thambyading bend, where the width from the root to the point of the bend is over ten miles. A curious exception is found in one place, near Yaygheen, where the river does not appear to have varied from a persistent main channel, whose width is under $1\frac{1}{2}$ miles between the permanent banks. To the south of the Thambyading bend the high flood channel is much more restricted than to the north. Its greatest width is under 4 miles, while for the larger part of its course its limits of variation are within two miles. And in the whole length of channel considered, especially below the Thambyading bend, the tendency of the complete flood channel is to become narrower and ultimately to coincide with that of ordinary flood, which keeps to a persistent main channel of little over a mile in width. At either end of this course of over 150 miles of river line, and of nearly 100 in a crow line, the river channel may be considered practically fixed to very narrow limits; while the interval has varied continuously. It has already been pointed out that the lower end corresponds to the torrent gully at the head of a conoid of deposit; while the upper extremity is fixed by rocky strata, not easily acted upon by the water.

Outlines of flood channel.

171. Again, on examining how the main channel is situated within the high flood channel, some distinctly noticeable features may be traced. From Saiktha to the top of the Thambyading bend the main channel appears mostly to hug the western permanent bank, except where a decided curve to the south of Saiktha, and a series of curves north of Thambyading throw it in certain parts towards the east. Even in these, and in most of the easterly turning curves, the main channel does not approach the permanent bank on the east side except above and below the great bend, where the local action has forced it far over eastward. The westerly tendency of the main channel is more marked in the upper half of the course considered than in the lower, where the oscillations go from side to side of the flood channel in a diminishing degree southwards. Its restriction to the part above the Thambyading bend and its manifestation in the most recent times, since the formation of that bend, would seem to link its existence with that of the development of this great curve of the river; and an investigation as to its cause and probable continuance will best be deferred until the conditions upon which this curve depends are determined.

Situation of main channel in flood channel.

172. The great Thambyading curve of the river, although in itself an abnormal, and so far as is known, an unprecedented aberration of the rivers course, is only an undue development of a phenomenon continually existing, and which appears to be an essential feature of this part of the river channel. Curves of a greater or less degree of acuteness and extent have always existed and still exist in this portion of the river, in different degrees of formation and progress. In the block plan of the river channel from Saiktha to Yandoon, several sets of curves can be distinguished. To permit a comparison of different stages of these, a second block plan, taken from Colonel Trevor's survey in 1855-56 is shown in Plate VIII above that taken in 1877 and its outlines are also given in dotted lines on the latter. Enumerating from the 1877 survey the more prominent curves from Saiktha downwards, we have one forming directly in front of

The great Thambyading bend.

The curves of the main channel of the river.

Kyangheen of a perfect S shape. Then, neglecting minor curvatures, which are locally important, but not yet oscillating widely, we have a series of curves commencing at the town of Monyo on the east bank, and extending downwards to near the town of Zaloon, the culminating curve and central factor of the whole being the Thambyading curve. A new set of curves, all of lesser intensity than the last, extends from Zaloon southwards to near Donabyoo. It would appear that any change of the river channel in any part of each series is propagated throughout the entire set of curves belonging to the series.

The Kyangheen curve.

173. The Kyangheen curve appears to have taken its present development entirely since the survey of 1856. At that time, the main channel was in course of transference from the convexity of a former bend, sweeping south-westerly from Poukteing to Kyangheen, and followed the chord of the arc, with a slight north-easterly curvature. The channel from Poukteing to Kyangheen continued still clear and navigable for some years, but has since nearly closed; the great sandbank between the chord and the curve progressing southwards to settle in front of the town of Kyangheen. It decends a few hundred feet yearly; and will before many years elapse probably come on to Myanoung. The main channel, which was nearly straight in 1856, has taken a distinct S shape. The upper part of the S rests against the rocky banks between Saiktha and Poukteing, whence it is diverged eastwards, yearly cutting off a piece of the upper end of the Kyangheen sandbank. The channel then takes a due easterly course to strike against the opposite bank, whence it is deflected south and south west just at present on to the west bank, where Colonel Short's Flank Embankment meets the Irrawaddy. Here and for 22 miles southwards the current is eroding the west bank. Its action is most intense at the point where it first strikes, and in the neighbourhood of Myanoung. It may be remembered that Colonel Short found that no erosion had taken place in this particular part, within human memory, and he accordingly gave a minimum retirement of 500 feet to his work there. Dotted lines on the large scale map show the edge of the bank at Malakagong in 1863 and the continuous line gives it at present. In a few places over 300 feet in thickness have been cut off the bank in the interval. As about 200 feet are still left between the embankment and the river the result so far justifies Colonel Short's choice of a minimum distance of alignment. And the fact that the Myanoung marginal embankment constructed in 1868-69 has mostly been taken up and removed to a further distance of 150 feet from the edge in 1878 would seem to bring with it a condemnation of the last work. There is, however, something still to be said on both points, which will shortly be again noticed.

Progressive changes in the curve.

174. The shape and position of the whole curve are continually changing. The arches of the curve tend to widen out over a greater east and west distance. At present this is $2\frac{3}{4}$ miles. The extreme ends of the curve, from point to point of the S tend to approach each other. They are now, from Poukteing to Malakagong, nearly 7 miles apart. The S broadens and shortens every year and this will probably progress until the sandbanks intervening between the arms are cut away, and these coalesce. Apparently the eastern convexity moves up the river, the western down. In reality the whole S curve travels downwards, and it is not impossible that a portion of Colonel Short's line will have to be retired within 3 years. Still more of the town of Myanoung may be eroded. From Myanoung southwards the main channel oscillates from one side of different islands to another; but always continuing to slice off small portions of the western bank, heaping up immense shoals and sandbanks on the eastern side. The whole of the towns on the east, Tsingong, Mengyee, Yeagheen, Monyo, and Teindaw, formerly large and flourishing places, and still populous, have been left during the last 50 years far from the river channel, and without the possibility of carrying on boat traffic, except in high floods.

Erosion of the western bank.

175. The length of main channel from Myanoung to Monyo, extending over about 24 miles is tolerably straight, and opposite that town it lies nearly midway on the high flood channel, surrounded on all sides with masses of the softest alluvion of its own deposit. Two or three miles south of Monyo it now takes a sharp turn westward, and after describing a nearly perfect semicircle of about 3½ miles diameter, takes a straighter course east of south for 5 miles, when it again performs an arc approaching a semicircle of 4¼ miles diameter in an opposite direction from the former. The two curves just described would, if they stood alone, form an ordinary S curve like that at Kyangheen, but of larger dimensions. But the second curve forms an intermediate stage of a series. It lies in the northern angle of the great Thambyading bend, at Pouknoo, and deflects the flow of the water towards the northwest to strike on to the permanent west bank at Loodauzoo, where it has cut away about ½ a mile of the end of the Myanoung embankment. From Loodauzoo the main channel in 1877 proceeded by a couple of nearly semicircular curves of 2½ miles diameter each, both convex westward to get round the existing point of the bend. It then follows a course slightly north of east to strike on the east bank near Sarawa, where it is forming the southern side of the root of the great bend. In all the course now described the river has manifested an excessive energy of erosion. Its course changes much from year to year, and no two surveys can correspond. From Sarawa there is a south westerly curve to Henzada followed by a corresponding south easterly one, the curvature being easier than before. A still wider and easier sweeping curve forming a semicircle of 6¼ miles diameter turns its convexity towards Doungyee and Zaloon, where it has been eroding the west bank and necessitating partial retirement of the embankment.

The Monyo Zaloon series of curves.

176. The river courses southward with continually diminishing energy of excavation. This by no means ceases in any part of its course to the sea. Even when broken up into several channels, the compensating process of excavation and re-deposit is found in operation, and what may be called incipient bends which never mature to the acute stage are being formed on both sides of its main channel. There are all the signs of a large bend similar though less acute than that at Thambyading having been formed between Zaloon and Donabyoo. There is a high permanent bank, forming a short road across the chord of the large curve existing between those two towns. The large Doungyee-Zaloon curve is slowly progressing down the river at the rate of about 1,000 feet per year.

Other curves of the river.

177. The great Thambyading bend has necessitated special studies both to ascertain its probable influence on the embankment works, and its ultimate effects on the Irrawaddy and Nawoon rivers. An extract was given in the last section from a report by the writer in 1869, showing all that could be ascertained then regarding the history of the changes on the river in that part. No very precise information regarding its early development was available. A direct comparison can be made between the states of the river in 1856 and 1877, including the whole of the series of curves from Monyo to Zaloon by the small scale block plan. A more detailed analysis of the changes about the Thambyading itself can be obtained from the large scale plan of this curve in Plate XIX, which gives superimposed the outlines of the bend at different periods. This permits the future development and final extinction of the curve to be approximately foretold. The importance of forming definite conclusions on these points may be inferred from the following extract from Government of India letter No. 89 I., dated 18th April 1878, commenting on the writer's report on the floods of 1876 on the Nawoon river. "The conclusion seems inevitable that the Nawoon was drawing off more water from the Irrawaddy during those two years (1876 and 1877) than it did in 1875, in spite of the Executive Engineer's positive statement to the contrary. The blocking up of the Thambyading creek does not prove that the other entrances may not before half a

Further information regarding the Thambyading bend.

The Government of India calls for further information as to the enlargement of Nawoon river entrances.

dozen years are over, be pouring through that very creek with greater force than ever."

"If on closer and more careful examination it should be found that there are reasonable grounds for supposing that the Nawoon is now drawing off or may hereafter draw off more water from the Irrawaddy than it did in 1875, I am to enquire what measures could be taken with any regard to economy, for regulating the efflux, and if the efflux must be admitted as beyond control within any reasonable limits of cost, to what height it is proposed to raise the Nawoon embankments? These questions merit grave consideration as if the future increase in height of floods is likely to carry the cost of the embankment above the limits of a remunerative investment, the fact should be clearly stated."

Details of changes in the Thambyading bend.

178. An examination of the whole of the changes in the series of curves will give the answer required. On comparing the block plan of 1856 with that of 1877 it is seen that all the curves above the bend and at the bend itself have taken a sharper curvature in the interval. Both the Monyo curve and the Pouknoo curve on the northern side of the Thambyading bend have descended the river very nearly two miles in each case. The north western curve of the Monyo bend appears to have taken a sharper curvature without advancing from its former position. The Pouknoo curve at the northern root of the Thambyading bend has cut into the eastern bank somewhat, in its southward progress. The intermediate survey of this made by Mr. Fennessy about 1865 permits the comparative rate of cutting southwards to be traced. The dotted lines show the 1856 survey; the red ones the 1865 one; the continuous black lines the 1877 survey of the bank. For the first nine or ten years interval the greatest progress made was over 3,000 feet, in the last twelve years, about 7,000 feet were cut away just at the neck. In 1878 another survey showed that over 1,000 feet had been cut away at one place in the one year. On the opposite, or Sarawa side of the bend there is a double tendency. In all these bends or curves there is a general downward direction, which is sometimes overcome by a direct upward local action. The lower side of the neck appears to have been subject to both modifying influences. On the whole there has been a tendency to deposit on this side; but the current has made a decided set into the extreme angle of the neck; and while excavating eastward about 3,000 feet, it has kept the deep steamer channel in the acute course of the bend, preventing any progress downwards just there. As a consequence of this, there remains only a width of 2 miles to cut through now, while in 1856, there was, at the same part, about double as much. The rapid increase of the rate of cutting of late years indicates an extreme limit of 10 years for the neck to be wholly excavated away in this part, when the Irrawaddy main channel will resume its former course here. It is extremely probable that this time will be much reduced from natural causes and the writer would fix about 5 or 6 years from this (1879) as the time of its breaking through if left to itself.

Probable time of river reverting to its old channel.

The Nawoon River entrances Views about closing them.

179. From the time the large embankment was designed until 1868, the action of the Irrawaddy on the openings of the Nawoon at Thambyading naturally excited much interest. It was the fixed intention of all the Engineers connected with the works to close all the openings, but the rapid progress of the point of the bend westward at last excited some apprehension. In the discussion raised in 1868 several diverse opinions were offered. Colonel Ardagh, Commissioner of Pegu, said under date 20th February 1868:—"I take the opportunity of desiring attention to the advisability of something being done to prevent what seems to me not unlikely to take place if left undone, which is the breaking through of the Irrawaddy into the Bassein river." Mr. Bennett, then Executive Engineer in charge of the embankments, speaking of the Thambyading

Colonel Ardagh's opinion.

opening says:—"The direction of the Irrawaddy here has so much changed that instead of running direct at the Bassein entrance, the force is direct on the entrance to the Thambyading creek. While at present on looking cursorily at the subject it would appear that the Irrawaddy has a tendency to relieve itself at this point to the westward, the creek is so small in comparison with the volume of the river that it is in my opinion very questionable if such be the case. The river has been gradually led against this point, and as the bend works further down (as it is now doing) it will again cut into the sandbank opposite and eventually resume its old course past Sarawa." After discussing the question of trade through this creek he says:—"It therefore appears to me to be a question of mere expense whether it is not better to bund up the creek altogether, and thus to secure the great object of the heavy expenditure that has already been incurred on this work; viz,, shutting out the whole of the Irrawaddy waters. This can doubtless be done by cutting an opening through the sandbank when the river would again return to its original bed and flow past Sarawa, clear away the great sandbank in front of Henzada, and steamers would again, as they did eight years ago, lie alongside the town."

Mr. Bennett's views.

180. Colonel Oliphant, for some years Chief Engineer of the Province, following Mr. Bennett's suggestion, wrote (28th May 1868):—"The Thambyading creek and Bassein river are the only two outlets to be dealt with, the latter is fast silting up of itself, and I would strongly recommend that immediate measures be taken towards closing it up entirely. The rapid enlargement of the Thambyading during the last 4 or 5 years is due entirely, in my opinion, to the manner in which the Irrawaddy river has been deflected from Pouknoo directly on to its mouth. It lies in the very apex of this bight and receives the full force of the main current, which is here very great. Now if there were no question of the construction of embankments on the east bank to be considered, I should unhesitatingly recommend the closing up of this creek also. I think moreover, that the longer this operation is delayed the more difficult it will be. It will be necessary in the first instance to lead the river into taking a more southerly course from Pouknoo, and for this purpose, I advocate that during the next working season a cutting be made through the neck, about 50 feet wide and 15 feet in depth, and a massive spur thrown out from the projecting point opposite to Pouknoo. The cost of the two works would be about Rs. 1,50,000 (£ 15,000)." If the first years operations were successful and the canal deepened, the spur was to be extended another 400 feet. Mr. Hallett, Executive Engineer, in charge of the embankments from October 1873 to July 1875, also advocated the cutting of this canal and took out the necessary surveys and levels. He proposed to dispense with a spur; his canal costing only Rs. 20,000.

Colonel Oliphant's views.

181. On the other side of the question the writer in his Report of 11th April 1868 urged the desirability of keeping both the Nawoon and Thambyading entrances open; with a view of relieving the Irrawaddy when the double embankment should be built. Colonel Brown, Commissioner of Tenasserim, strongly recommended that these and all the other large outlets should be left open. Colonel Fraser reviewing the whole papers took the same view, principally on account of the decided set the Irrawaddy was making in the direction, which seemed to indicate the natural drainage line of the country. The Government of India, in the letter quoted in the Introduction to this part of the Report, sustained the opinion that these rivers should not be interfered with; and gave orders to that effect.

Opposed views. Decision of the Government of India.

182. The double small curve now forming the point of the bend turned westward, did not exist till 1874. From 1855 to 1873 a single curve turned its apex on to the mouth of the creek at Thambyading, where it persistently excavated away the bank. Its progress westward corresponds with that of the Monyo and Doungyee curves southward. In the first 9 years (1856-1865) it

Advance of the curve on the river bank.

advanced nearly 4000 feet west, cutting off a slice of ground 5 or 6 miles in lineal extent round its outer perimeter. From 1865 to 1873, or in the second 9 years, the rate of advance increased, and about one mile in width on an average was excavated in the immediate vicinity of the Thambyading entrance. The greatest width of excavation was over 1½ miles in extent, in the period 1855-1873. It cut away a portion of the site of the intended embankment, including the place where it was proposed to put the dam or anicut to close the stream. To the south east of the Thambyading, and between it and the Nawoon the erosion previous to 1873 had been very heavy. To the north it was, in the latter period, much lighter. The village of Noukmee altogether escaped for several years. But, in 1873, the excavation on the Thambyading entrance practically ceased. The original large curve broke into two, one taking a north easterly direction, the other a south easterly. The northern curve has retrogressed, as it were, upon the Pouknoo one, and has passed steadily up the river cutting off a slice of the bank the whole way from Noukmee to Loodauzoo, where it is at present exercising its greatest eroding action. It has here cut off over 2,000 feet in width of the bank, where the embankment had been constructed at an average retired distance of about 1,000 feet The apex of the curve continues to move in a north easterly direction yearly, and up to the present time (1879) about 3,500 running feet of the lower extremity of the embankment has been carried away. A study of the whole series of curves, and a comparison of the progress of their changes proves that this Loodauzoo curve will continue to pass to the north-east year by year, with increasing rapidity, as the Pouknoo curve gets more acute. The action of the latter on the root of the neck of the bend tends to increase in intensity. A corresponding sharpness of form and rapidity of erosion follows in the Loodauzoo curve. The exact rate of progress or the probable amount of embankment to be lost cannot be foretold. But there is one circumstance which makes it probable that before long the end of the embankment may escape from this erosion. A well consolidated sand bank increasing rapidly in width to from one to two miles lies in front of the bank above Loodauzoo. The main channel will probably find in this sufficient scope to exhaust its energy of excavation upon. It is only now commencing to feel this sand bank, and the next one or two years floods will demonstrate whether the hope now expressed is well founded or not.

183. The interval between the newly formed main channel and the Thambyading entrance has been filled with sand banks. The former channel, where the greatest intensity of cutting existed, is now a quiet lagoon abandoned by the river, and forming the sole means of communication for the dry weather with the Bassein river. A sandbank slowly protrudes year by year over the mouth of the Thambyading; but its increasing distance from the principal focus of erosion renders it yearly less liable to be wholly closed. This is particularly fortunate in the interests of navigation between Bassein and the Nawoon river stations and the Irrawaddy. The only obstacle to the continuous navigability of the whole line of communication is likely to be found here. The Irrawaddy Flotilla Company are shortly about to open a new line of steamers on this route, from Henzada to Bassein; and the writer accompanied the Agent lately to examine its suitability. If the Thambyading remains open, or can be kept open economically, the general interests of the Province will be best met by this being done. The closing of this channel can bring only local benefits; which, perhaps, can be secured by other means. It will be a great misfortune if the Thambyading shares the fate of the Nawoon; but this contingency must also be contemplated; as it is quite impossible to predict from our present data, what the course of the river may be in a few years, especially when the neck of the bend has been cut across.

Formation of sand-banks of lagoons.

Desirability of keeping open the Thambyading.

184. At present, although the channel itself shows no signs of lessening, the Thambyading creek does draw a smaller supply of water from the Irrawaddy than before in as much as the swiftest current formerly feeding it is

Smaller contribution from the Irrawaddy to the Nawoon river.

diverted wholly away from it. It now draws its supply from the side channels of comparatively quiet water. The Nawoon continues steadily to decrease in size at its mouth; and the water flows with only a slow current to the Nawoon main river. A fresh source of supply has, however, opened to the Nawoon river since 1873, over the banks where the Loodauzoo curve passed up stream cutting away the embankment and the elevated natural embankment characteristic of the whole of the rivers' banks. The simple fact of removing 3,000 feet of embankment opened a new channel over the ground of that width, with a probable flow of eight feet in depth, which must have found its way to the Nawoon. But a most important fact must be here noted. It is, indeed, the most important factor in determining the judgment on many points connected with schemes for embanking the sides of great rivers flowing through their own soft deposits. As the river has been cutting away the high edge of the ground all round the periphery of this great Thambyading bend, it has continually thrown a large part of the excavated matter on top of the contiguous banks.

The elevating process on the river banks.

The excess of silt found in the immediate neighbourhood of the erosive action has also found a resting place from the water passing over the bank in its flow from the river. As the high ground on the edge disappeared, the old natural level of the ground behind, often 12 to 20 feet lower than the flood, received fresh deposit. The writer has had continuous opportunities for noticing this action in these parts during the last 10 years. He has found several feet in thickness of silt piled up on the ground after a seasons flood, where the previous year he has walked on the clear low ground. As a result the entire new permanent bank of the river here is now almost at a level with the highest floods. From Nawoon to Thambyading the operation is nearly complete, as the bank has had a longer rest there. It is progressing rapidly from Thambyading to Noukmee; the three miles of intervening bank getting nicely raised and consolidated. From Noukmee to Loodauzoo, the river is finding out the lowest places, sometimes opening into large low lakes. Here even, it proceeds regularly to raise the ground. On this part particularly the writer has multiplied his observations and surveys, in connection with projects for finishing off the Myanoung embankment. And here at present can be seen the whole of the stages of the rivers operation side by side. At the end of the embankment which stands high above the ground at the rivers edge, the process of deposition is checked while excavation is in full force. For about a mile to the south-west the greatest activity of excavation now extends. The silt and almost solid sediment is here thrown up simultaneously with the excavation. Lower down, the current is gradually diverted from the bank; which has been already raised, and is now being thoroughly consolidated by the finer silt from the flowing water, whose energy is checked and lost in passing over the bank (1).

185. It has been a great misfortune for the Myanoung embankment and has detracted greatly from the success of that work to have come within the sphere of operation of this excavating energy of the Irrawaddy at Thambyading.

Suspension of Myanoung embankment works justified by the results.

As the result has proved, the leaving open the Thambyading creek, and the suspension of the works from the 44th to 50½th miles in 1868 were both justified. But the flood water passing over the bank below the end of the work finds its way behind the embankment and prevents cultivation extending in the lower parts of the Myanoung plain, which it was intended to protect by this work. Several distinct projects, which the writer has had to take up and examine have been devised for overcoming the difficulty, and excluding the water from the plain; of these a detailed notice will be given in the next part of the report; but the writer after a thorough investigation of all of them has been

(1.)—In this account of the excavation and deposition of silt on the edge of the bank the writer somewhat differs from Mr. James Fergusson, the able architectural writer and archeologist, who, in his paper on the delta of the Ganges, considers that the masses of still water, called Jheels, lying on the edge of the banks of rivers flowing through alluvial deposit, cause the silt to fall and accumulate through checking the flow of the river water. This undoubtedly is efficacious as far as it acts; but the immense masses of silt found on the Irrawaddy edge could only be brought by continual fresh arrivals of slowly flowing water; which lose most of their energy on the edge of the bank; but require more beyond, and pass away to make room for further supplies both of water and silt.

compelled to the conclusion that until the river erosion entirely ceases on this line of bank. no action whatever should be taken. It was on his representations that the continuance of the work from Loodauzoo was suspended. From the progress of the erosion, as stated above, he considers that in two years it will have left entirely the neighbourhood of the embankment line; and though, previously, he could fix no date even approximately for that expectation to be realized, any influence he has, has been exerted to leave the works in their present position till this manifestation of river energy should be exhausted. An excellent new elevated bank will then have been formed on the rivers edge. No further erosion need be apprehended. The embankment can thus be continued on high ground the whole way it seems desirable to carry it. Should the Thambyading close of itself, the original scheme can be carried out at small cost and the work be joined on to the Henzada one. Should it remain open the line of embankment can be taken down the right bank of the creek, as far as the mouth of the future drainage channel of the interior.

Resumption and completion of these works soon practicable.

186. This position has been consistently held conjoined with another, *viz.*, that it is at present inexpedient to take any steps whatever to interfere with or to attempt to control the river action on its banks. In this the writer has been opposed by most of the Engineers who have been connected with the embankment works; and in face of their expressed opinion, and in what may be called the disadvantageous results which have followed from it in the loss at Loodauzoo of 3000 feet of embankment; in the encroachments of the river from Kyangheen southwards past Myanoung and the necessitated removal of the marginal embankment there; in the removal through river encroachment of a part of the Henzada marginal embankment, and in the late and present retirements of the embankment in the face of the Doungyee-Zaloon curve, it requires that the reasons for such a *laisez faire* policy should be distinctly stated, in order that if it be disapproved of, it may now be changed. A full justification of it can only be given when the financial aspect of these works and their relation to the economical wants of the country are considered. In the meantime the engineering and physical conditions on which it is founded may be briefly noticed.

Undesirability of undertaking great regulating works on the river channels.

187. The opinions of Mr. Bennett, Mr. Hallett and Colonel Oliphant, all of whom have had direct control of the works, on the point of regulating the river channel can be gathered from their expressed recommendations to open a new channel across the neck of the Thambyading bend. Opportunities existed for them to have carried their views into practice; and it is not understood why they were not realized, especially in 1868, before the writer took charge of the works; and in 1873-75 when away from them. To the authority of their opinions must be added that of Colonel Stoddard, an Engineer with 15 years experience on hydraulic works in Madras. Colonel Stoddard in his Report of September 1869, gives a valuable description of groyne or pier works on the Godavery and recommends their use for controlling the Irrawaddy. These groynes are built up of fascines made of bundles of elephant grass interwoven with cords, and loaded with clay. They are arranged in spurs and staked down to the bank of the river. In its upper part the bank is sloped off. There can be no doubt that in certain circumstances such spurs will be extremely valuable. Colonel Stoddard says :—"These spurs are very useful in removing sandbanks which are beginning to form in the bed of the river, and so endangering the banks by deflecting the current against them. I should think that a fringe of such groynes or spurs judiciously placed around the inside (western side) of the sharp bend or both sides of the Thambyading creek would most effectually preserve that bank from *caving in* as it is now rapidly doing and if it be desired even to prevent the Thambyading from getting any wider, one of these spurs on each side of its mouth projecting into the river some considerable distance would answer the end at once. I have mentioned that these spurs are of great use in causing the removal of sandbanks. I may also state that *eradicat-*

Opposite views discussed.

Colonel Stoddard's proposals.

ing the grass which begins to grow on these banks helps still further to get rid of such nuisances. Had some such measures as those now mentioned been adopted at Henzada long ago, the river would now have been *close* to that town instead of the large sandbank that is there."

Reasons for not adopting such proposals.

188. If there were probability of such measures as those indicated resulting in a permanent improvement of the river course, or in such a guidance of its eroding action as would in any way mitigate the inconveniences above noted, only culpable negligence could have permitted these erosions to continue, bringing with them as they do grave difficulties connected with the removal of embankments; and the loss of entire town frontages with houses, gardens and land. The reasons for not recurring to these or other such expedients on the Irrawaddy during the last 10 years are of two kinds:—general and special, the first derived from a consensus of authoritative experience on other rivers; the second based on the peculiar financial and physical conditions under which the task to be imposed would have to be performed.

Difficulty of cutting across a bend of a river.

189. Under the first head we may consider the testimony of competent Engineers on such a simple task as that proposed of cutting across the neck of the Thambyading bend; which has received the sanction of three Engineers directly in charge of the works. A task of this kind is not so easily achieved as is supposed. The case may be remembered of the Americen army before Vicksburg on the Mississippi in the war of 1861-64, which for several months was engaged cutting a canal across a similar but much narrower neck of land (about one mile in width) in the vain hope of diverting the Mississippi to a new channel so as to avoid the guns of the fort. Notwithstanding the abundant resources and skilled labor employed for a considerable time, the effort was wholly unsuccessful. When Colonel Oliphant proposed to make a cut across the neck of the Thambyading bend at Doungyee the distance was nearly 3 miles across. The proposed works, a canal 50 feet wide, 15 feet deep and 3 miles in length, with a spur from the opposite shore would have cost quite the estimated amount of £15,000. On carefully examining this neck it was found that several such channels existed naturally, of dimensions much larger than that proposed to be cut. One was levelled and surveyed by Mr. Hallett in 1874. The survey and level are given in Plate XIX. This was a remnant of the old main channel of the river and lies just at the root of the neck. When surveyed it was over 3 miles long, with widths varying to some hundreds of feet, and depths of water at high flood of from 12 to 27 feet at all places but the extreme upper end, where a high bank about 1000 feet wide and nearly to the level of high flood occupied the entrance. The surface fall at flood is nearly 3 feet per mile, the general fall of the river being only 4 inches. Mr. Hallett, considered that by removing the mass of silt at the entrance of the natural channel at a cost of 15,000 or 20,000 Rs. the river would cut across the bend of itself. Both his and Colonel Oliphant's proposals are founded on a misconception of the river action.

Natural cuts across such bends.

This river at present fills such cuts.

190. The entrance of the creek referred to lies just in the apex of the Pouknoo curve, where the erosive action of the river carries away over 1000 feet in width of the bank yearly. It must, then, have entirely removed the whole of the accumulation of silt with the ground on which it stood since 1874; yet no progress is made by the river in enlarging this creek. It rather tends to close it. In every flood as it cuts away the bank, it throws up, in the manner already described for the bank south of Loodauzoo, a great portion of the excavated earth upon the edge of the remaining bank. Mr. Hallett's levels show the result of one seasons work in filling the mouth of the creek; a process which is repeated every season and as fast as the old bank is cut away. A similar deposit now exists in this creek; and the first thing the river would do on topping the bank, if this deposit were removed, would be to replace it. If any natural excavation takes place it must be from the lower end, and work backwards to the upper. And in this mode the

neck will ultimately be cut across. As the distance shortens, say to one mile, the total flood surface fall of 8 or 9 feet will probably remain the same as in 1874, or as now. The water on first flowing over the bank is checked in its motion. It loses its energy, the silt it holds falls, and the clearer water again flows on deriving new energy from the fall in its new course. At present this total fall being about 8 feet in two miles is not sufficient to generate in the restricted channel referred to sufficient energy to excavate the bottom of the channel; especially as the water in the lower arm holds back the discharge. But as the distance shortens the energy developed will increase; and it is extremely probable that when the distance across is reduced to one mile, or less; which at the present rate of progress will occur in less than 5 years, this channel and others like it, will of themselves deepen their beds so much as to be able to carry away the whole of the silt thrown up by the Irrawaddy at their upper ends. When this happens, the Irrawaddy will resume its old course across the neck of the bend.

Future prospect of the river opening these cuts.

191. The consequence of this may not be altogether so favorable as has been anticipated. It must have been some contemplation of this certainly happening, which induced Mr. Fennessy to retire the large embankment so far from the river's edge near Henzada (over half a mile) as he has done. There is every probability of the excavating action of the new main channel being turned on to the town of Henzada some 5 or 6 miles south of the bend. Whether in this case it would be an advantage to use the embankment where it stands, is doubtful; and the Government will incur a grave responsibility for damage to property in the town if it decides to maintain this great rear work, and hold water up to depths of 12 to 15 feet in the area of the town, which lies wholly between the rear embankment and the river. The writer distinctly recommends that sufficient provision be made for the escape of the flood waters to the interior through this work in case the Irrawaddy floods ever break through the marginal embankment. The embankment as it stands is of great use as a road, and will always continue so, but whatever protection it may give to agriculture in the interior will be at the cost of the property in the town. At present it is not high enough to withstand great floods like those of 1875 or 1877, and is thus only in a position where it can do damage, without affording complete protection. These views have repeatedly been placed verbally before the local professional authorities; but as the contingency of evil happening seemed distant, no practical result has followed. The danger at present assumes a distinct and definite form; and the above recommendations are now placed upon record with a view to timely measures being taken by responsible authority.

Danger arising from cut offs.

Grave danger thereatened to the town of Henzada. Recommendation of provisions to meet it.

192. The highest authorities on river hydraulics are unanimous against trying to improve the régime of a river by "cut-offs" across its bends. Colonel Suter,(1) United States Engineers, in charge of the Mississippi and Missourie Works, thus writes regarding the Mississippi "cut-offs":—"On the Mississippi itself the continual erosion of the banks gives rise to some curious phenomena, the true office and explanation of which seem not to be generally understood. I allude to the cut-offs which from time to time are formed naturally, and which are constantly brought forward by speculative individuals and advocated as a panacea for the ills resulting both from floods and low water. In the first place it would appear at a casual glance that as the cutting action is greatest in the deepest recesses or apices of the bends, there would result an indefinite elongation to the right and to the left of the general direction of flow of the river, or at least it would be carried to such extent that the consequent reduction of slope would destroy both the velocity of the current and its power of transporting the mass of sediment poured into it, such

Warnings against causing cut-offs. Colonel Suter.

(1.)—Suter, Colonel Charles. R. Report of Chief of Engineers for 1875 II, 497, Washington.

would indeed be the case, although the consequent filling up of the bed would gradually raise the whole river and finally establish new conditions of equilibrium.

"But in truth the remedy is far more promptly applied, the cutting of the bank is not confined to the apex of the bend, but extends along the whole concave shore, and as the bends overlap each other, it follows that the necks of land separating them are eroded on both sides, and hence are rapidly reduced in width.

"In the course of time the dividing neck becomes so attenuated as to be no longer able to sustain the pressure of the water against it, and as the nature of the materials of which the bank is composed allows more or less water to leak through and wash out the sand-layers, finally the whole mass crumbles, and a wide breach is formed through which the rivers pours with resistless force. Davis's, one of the most recent of these cut-offs, and also the largest occurred in 1867. It cut off Palmyra Bend, eighteen miles below Vicksburgh, a bend which was eighteen miles long, while the distance across the neck was only 1,200 feet. The exact slope of the river at the time is not known, but it was probably not far from 0·3 foot to the mile, therefore the difference of level on the two sides of the neck was about 5½ feet. When the river broke through, the whole of this fall had to be absorbed in the 1,200 feet of distance, making a rate of about 24 feet to the mile; and it can readily be imagined that the the whole immense flood volume of the Mississippi, flowing with the enormous velocity due to this great slope produced very marked effects. The roaring of the waters could be heard for miles, and in the course of a few hours a channel a mile wide, certainly over a hundred and probably nearly two hundred feet in depth, had been excavated. Even then it was many weeks before the velocity of the current had sufficiently abated to allow boats to use the new channel.

"It is clearly evident that in such cases as this the stream cannot long remain in a condition so different from its normal regimen; the length by which it has been shortened must be regained, so as to restore the usual slope and this can only be effected in one way, *viz.*, by the elongation of bends lying above and below the cut-off. This result has followed in the case mentioned, and is, and must be an inevitable accompaniment of any similar occurrence. The influence of the Davis cut-off is still felt far above and below Vicksburgh. The rate of erosion in the bends has been enormously increased, and to-day we are threatened with several more cut-offs between Memphis and Vicksburgh. One in fact occurred during last summer, near Commerce, Miss.

"After the river has once formed a new channel for itself; the old bend fills up at the head and the foot and becomes a lake. The immense number of these peculiar crescent shaped lakes scattered through the bottom lands on both sides of the river, shows that this action has been going on ever since the Mississippi has existed in its present state, and we would therefore seem justified in assuming that no material change has occurred, within recent times at least affecting the slope, length, or general direction of the stream.

"Such being the well recorded effects and results of cut-offs, it certainly is surprising to find that, from time to time, their formation by artificial means has been recommended as a means of improvement, and some have actually been produced, or at least hastened by ignortant persons. The amount of damage produced by a cut-off, particularly in those portions of the country where riparian plantations are numerous, must necessarily be enormous; and as I have attempted to show, no good is likely to result therefrom, as the river will in time be precisely in the same condition as before."

General Abbot's warnings and recommendations.

193. The Committee for considering a permanent plan for the reclamation of the alluvial basin of the Mississippi subject to inundation thus express through General Abbot their very first recommendation. "Cut-offs." "Ex-

act observations upon the Po, the Mississippi, and other rivers have established that the effect of a cut-off is to raise the water level just below its site by an amount equal to half the fall in a straight portion of the river of equal length, and to depress its height just above by an equal amount, plus the head requisite to overcome the resistance due to the curvature of the bend. If it were possible to extend the system from the foot of the alluvial region to its head, the result would be to greatly raise the flood level in the region below and to depress it in the region above the middle point. Hence, even if no other injury than this of submerging the lower half of the valley would result the plan would be utterly inadmissible either in an engineering or a political point of view. But this is not all. The local increase of velocity and change of direction of currents resulting from a cut-off, increases the caving in the bends both above and below its site. Indeed it is largely due to the frequent occurence of these interruptions to the normal conditions of an unvarying river-bed, that the excessive caving in the upper part of the alluvial region is to be attributed. Five of them have occurred during the past quarter of a century, all with disastrous results to the river. So far from artificially aiding in their recurrence, it is therefore the emphatic opinion of this commission that in every case they should be prevented, or at least retarded, if this can be done at any reasonable cost."

Other warnings—Dubuat.

194. The authority now quoted is amongst the latest and the highest we possess in such subjects. It is sustained by most modern and by much older experience. Dubuat is somewhat undecided between two desperate alternatives (1). "On the one side" he says. "How much has not been spent in repairing embankments which have been carried bodily away; in groynes, in drainage canals, in raising streets and houses in towns and in necessary repairs; without mentioning the land consumed often in pure loss by the sinuosities of rivers, of the embankments for the draught of vessels and of the loss of time to navigator." He suggests occasional cut offs "but." it must be allowed that this means of remedying the overflow and preventing the rupture of embankments is frightful (*frayeux*). "It may happen that in making too many cut-offs on a river, occasion is given for accidents nearly as bad as those that we wish to avoid, for the velocity of the current, become more rapid by the augmentation of the slope, may increase to such a degree as to deepen the bed and eat the banks; which will give place to numerous damages, of which the least will be to render the bed variable and uncertain, confounding the properties of the riverain dwellers, without speaking of the still worse effects which will result to the villages and towns, where buildings, bridges, and quays will be in danger of being ravined little by little underneath, and of being overthrown."

Guglielmini's warnings.

195. Going further back to an equally great authority with Dubuat, we have Guglielmini's testimony on the universal difficulties met with in interfering with river action (2). "The necessity that men have had to hinder the voracity of rivers which in the corrosions of their banks and changes of course swallow the sustenance of families, abandon bridges, cut up roads, and intercept free traffic, with a thousand other evils has been the means of turning the minds of engineers to seek remedies and to investigate the causes; whence it happens that no other part of hydraulics has been more treated upon than this. There is need to confess that so far it has been without much profit, either that the causes occasioning the corrosions and changes of course are too multiplied, or that it has been too difficult to measure their energy so as to proportion the resistances; or that it is exceedingly easy to mistake the true cause producing the effects it is desired to remove "*E perciò il piu delle volte vananente si traviglia, ed inutilimente si spende il tempo e il denaro, in volere resistere al corso incamminato d'un fiume*" "and thus most often are the works, and the time and the money spent in vain in trying

(1).—Report of Chief Engineers for 1875 I p 540. Washington.
(2).—Dubuat. M. Principes d'Hydraulique 1816 I p p 182 184.

to resist the moving course of a river. Many a time the remedy is worse than the ills. The cases are not rare in which an attempted improvement has brought about in a single day the ruin of a bank which without it would have resisted a longer time."

And, finally, in quoting one of the oldest and best authorities we have on the subject we find there is still a concurrence with the most modern counsel on the matter. Leonardo Da Vinci is clear and explicit in his directions for regulating rivers (1). "When a river is too straight it is too swift and corrodes much, consuming both embankment and bed. It is necessary to lengthen such rivers much either by giving them many tortuosities or by diverting them into many branches. And if through excess of sinuosity, lagoons and swamps are formed, they should be straightened so as to give them sufficient flow; but not enough to bring ruin to their banks or embankment."

Leonardo da Vnici's counsel.

196. There is here a great weight of testimony which gives *prima facie* grounds for incredulity when we are told that such simple means as those proposed for the Irrawaddy are likely to result in the permanent improvement of the river. That there will be great changes in the course of the river when the Thambyading cut-off takes place is certain, but that they will be wholly beneficial is most improbable. As shown, there is reason to expect that the action on the lower end of the Myanoung Embankment will cease in a year or two, without resort to such desperate expedients as cutting across the bend. If it were possible to seize that particular stage of the river's action, where it is in all probability the least injurious on the whole, and then to stereotype it as it were into a permanent form by regulating works, one of the gravest problems of river hydraulics would be solved. This is what the extensive regulating works on so many rivers aim at. But the execution of such works sometimes extends over scores or hundreds of years, and necessitates the expenditure of millions of pounds sterling. The Rhine is a small river compared with the Irrawaddy. It runs through several different states all of which take common action to control the river. Much success has been attained, but the cost is incomparably beyond what can be afforded for the Irrawaddy delta at present, and numerous failures are to be found recorded for this and for other European rivers.

Weight of testimony in favor of leaving the river alone at present.

197. Dr. Hagen (2) records that the celebrated hydraulician Herr Wiebeking applied an immense number of spurs to the Rhine banks near Dusseldorf. "After a few years they were wholly untraceable." He insists on the necessity of each set of works being complete in itself before the season in which it is to be tried comes on. He points out the necessity, if spur work is to be used, of it consisting of a large number of spurs regularly placed, and connected with an unyielding shore so that they cannot be attacked in the rear. He ascribes the great mistrust prevailing in France regarding such works to certain failures, instancing Defontaine's account of the Rhine works below Strasburg, where the régime of the river was thrown into the utmost confusion and disorder through the bad arrangement of the works, which were totally destroyed in 1840 (3). He further notes how an experiment tried on the Loire, where three long spurs, which were run out into the river at too great distances apart to have a common action, had no other effect than to introduce confusion into the current of the stream. No benefit of any kind was experienced. He is emphatic in condemning the use of single spurs. His words are.—"It is therefore clear, that single spurs, particularly when they protrude much, so far from regulating the stream, only increase its irregularities."

Regulating works on the Rhine. Great cost and failure of some works.

(1.)—Leonardo da Vinci. Dell Moto e Misura dell Acqua VI,

(2.)—Hagen Dr. Wasserbaukunst

(3.)—Champion M. Maurice, Les Inondations en France.

198. M. Minard, whose works on river hydraulics continue standard references, in a memoir on the mouths of navigable rivers (1), makes the following remarks. "If the amelioration of entrances has always exercised the sagacity of engineers, and has been rarely undertaken with success, it is because this question is one of the most complex that art has to deal with, there being few where so many variable and unforeseen elements enter. It is remarkable to see the assurance with which many engineers have accosted it and the promptitude with which nature has upset their provisions." He describes and discusses certain works on the Rhone, on the Adour, and on the Seine, in their lower parts, showing how often these fail in their effects, and the enormous amount of money sometimes lost with only uncertain results. The works referred to by him in the Seine have been lately described. Beneficial results had been obtained in a portion of the river, but in the bay outside they had been far otherwise. The probable result will be to seriously affect the port of Havre. The cost of these works, which extend over only 37 miles of the lower course of the Seine, was, up to 1876, £678,000. The Rhone works are those before mentioned as being an utter failure. M. Minard considered it was probable that the beneficial effect of the Adour works might last 20 years; their cost up to 1863 having been £60,000.

M. Minard on river regulating works.

199. Numerous other examples could be cited showing the disastrous results of failures of attempts to regulate rivers, where the attempts have not been maturely considered, and on a sufficient scale. The Roorkee publications contain instances of success and of non-success in such works on Indian rivers, but it will be evident on studying these records, which generally relate to works on a comparatively restricted scale, that when success has been in any measure achieved in guiding such rivers as the Sutlej, the Gogra, the Gunduck &c., only the utmost attention of a somewhat extensive skilled supervision has been competent to render even temporary amelioration at certain spots. Some excellent papers, amongst the older ones those by Mr. Longmore, Mr. Anderson, Captain Brown, Mr. Stony, &c., describe the means adopted and the results attained. But they fully prove that success even on a small scale must be purchased at a great cost. Thus Mr. Anderson notes that four protective spurs for the Phillour Bridge over the Sutlej cost 80,000 Rs. each; the total cost of the proposed works being Rs. 7,55,000. Mr. Stony gives an account of some successful operations on a short reach of the Gunduck, which carries 270,000 cubic feet of water per second in flood, but he pertinently remarks:—"It is a mistake to suppose that intermittent attempts at controlling rivers of this description are sufficient. Works of this nature should be permanent, if the protection is to be permanent. No extent of shoal or sand bank can be depended on for one season, as a protection. A mile in length and half a mile in breadth can be melted and carried off in two days if the river set on it. It is necessary therefore to have them repaired, extended or modified every season, there is no such thing as turning a river of this sort once for all, and then leaving it safe." He does not give the cost of the works described. Lieutenant Shepherd describing brushwood spurs on the Damooda, says they cost not less than 9 Rs. per foot run. Some ten spurs on the river at Lahore are described by Lalla Kunhya Lull, as having been effective in diverting the stream, which is, however, a small one, 200 feet wide, and with a long straight reach favorable for the work above the site of the works.

Practice in regulating Indian rivers.

(1.)—Minard M. Les Embouchures des Rivieres Navigables 1864.

From M. Champion Inondations en France.—The opposed projects of straightening a river course and of keeping it lengthened in sinuous curves were brought out in striking contrast on the Rhine by a dispute between the Engineers of the Duchy of Baden, and the French Government Engineers. The former approved the straightening of the course. The latter the preserving and regulating the curves. The course of the river in Alsace was subjected to both treatments, the one on the right bank, the other on the left. This lasted for 15 years. The contest and the results are thus described by M. Champion. "Les Inondations en France" 1863 V, xxx. "les Badois persisterent dans leur tracè à peu près rectiligne, pour figurer la limite assignée à la rive droite du fleuve; les Francais subordonnerent à des alignments fictifs, composes d'une suite de courbes alternativement concaves et convexes les projets des ouvrages defensifs de la rive gauche. Il est aise d'imagineer le desordre que devait produire, dans le lit du Rhin, l' execution de travaux conçus de la sorte, ayant dès directions sonvent hostiles, laissant enter les deux rives des largeurs tres-variables. La Guerre des principes se traduisit donc en une guerre disastreuse sur la terrain, et cette guerre combinèe avec les inconvenients des ouvrages saillants durant les quinze années de 1815 à 1831, eut pour consequence, pendant les crues extraordinaires de 1824 et 1831, la destruction de presque tous les travaux executes à grands frais et sans accord entre les deux rives."

200. Amongst the later practice on Indian rivers, most valuable experiments are recorded by Mr. Graham on the Sutlej in 1874, where the floating weed spurs introduced by Colonel Brownlow were applied together with fixed brushwood spurs. The former consist of large hawsers anchored down at their upper ends and floated with buoyant casks &c. To these trees and brushwood are attached. The object is to check the force of a current in front of a part attacked, and cause silt to deposit. Mr. Graham's works were designed to lead the main channel of the Sutlej through the Adamwahan bridge, and they extended over 5 or 6 miles in length of the river, which is here shallow and broad, and tolerably straight. In one season 80,000 Rs. (£ 8,000) were spent. Colonel Piele says of the effect of these works. "I consider the results of this season's operations are very encouraging, and afford good grounds for the hope that the oscillations of the river may be restrained with some degree of certainty between fixed limits, but I am still of opinion that a considerable expense must be incurred in some more permanent and solid constructions near the bridge, which may serve to give some security to the approaches, in case of the failure of the temporary obstructions." Other similar works are described for the Indus at Deri Ismael Khan, where tree spurs, each tree being anchored separately to the bed of the stream and arranged in series joined together, were used. The works executed in 1875 were partially effective to divert the river from the station, but Major Thorold R. E., recommended additions in that year to cost 40,000 Rs. As in the former cases only temporary results could be hoped from these works. Mr. Ivens describes some larger works on the Indus near the head-water of the canals. Tree spurs and floating spurs were used. The cost of the former was 25 Rs. per running foot. About 20 of the Brownlow spurs were used, but without satisfactory results, as they were too few in number.

Expense of temporary expedients.

201. These instances of actual practice are brought forward to show that even in India where the cost of labor and materials for such work is from $\frac{1}{2}$ to $\frac{1}{3}$ of what it is in Burma, it is no light task to undertake the protection of any given point of river, under such favorable conditions as shallow channels, straight courses and easily manageable rivers give. A single extract from a leading Indian paper, "The Pioneer" of February 19th 1876, requires no comment, as it shows what may be expected in unfavorable conditions, when a large river makes a direct set against a part of its banks. "The works carried out from time to time to protect the Eastern Bengal Railway terminus at Goalundo have cost nine lacs of rupees (£ 90,000), and added £ 600 a mile to the cost of the line. They have all been swept away by the Ganges which has so far defeated the Engineers."

Failures on Indian rivers.

202. It has only been after the fullest consideration and closest study of the question from time to time as the different cases presented themselves on the Irrawaddy, that the writer decided neither to support nor to recommend the adoption of any defensive works whatever on the threatened parts of the bank where the embankment stands. A close examination of the large plan of the Thambyading bend (Plate XIX) will prove incontestably that any such works as the pier proposed by Colonel Oliphant and spurs of Colonel Stoddard must be without any effect whatever upon the river. The main channel is there about a mile broad, and eighty feet deep at flood. The deepest part always lies close under the bank in course of being eroded. The surveys of 1877 and of 1878 show the nature and extent of the action taking place in a single flood season. On the Pouknoo side the excavation appears to have extended over about 5 miles of the convex bank of the river, ranging in thickness from nothing to nearly 1,200 feet. A corresponding deposit took place on the convex bank for a considerable distance; but erosion afterwards sets in when the current is diverted from the Pouknoo side and sets towards Loodauzoo. Then for another 5 miles or more the western bank is eroded to breadths

The writer opposes the adoption of any such works at present.

up to 600 or 800 feet. A spur on any part of the convex bank where deposit is going on would be simply silted up, and disappear under the accumulation of sand. As generally admitted, one alone would have no good effect in diverting the stream, if placed elsewhere in a more suitable position.

Opinions expressed in 1870 on Colonel Stoddard's proposals.

203. In 1870 the writer thus reported on Colonel Stoddard's proposals:—"It has been proposed to control the river action by diverting the course of the stream as occasion arises. Colonel Stoddard suggests two means of doing this:—1st, by groynes of grass and clay fascines, to throw the stream off the bank; 2nd, by plucking out the grass which grows on the newly formed sandbanks. By these means, he says, the further cutting away at Thambyading may be prevented, and a large sandbank, which within the last ten years had shut Henzada out from the river channel, might have been removed. If this could be done at reasonable cost very great benefit would arise, and the question of the position of the embankment be satisfactorily settled. But when the river acts on a bank, as at Thambyading, the deepest part of the channel goes over to that side. This is sometimes over seventy or eighty feet in depth, and a groyne even of grass fascines would be expensive. To be effective, many of these must be used, especially when the action is so great as at Thambyading; and it is doubtful after all, owing to the soft nature of the banks, whether the groynes would not be carried away bodily. The bank does not wear away gradually. I have seen slices from two to three hundred feet long, and forty or fifty feet deep settling gradually down, and cracks appearing some distance from the edge premonitory of future subsidence. Grass does not grow on new sandbanks for some two or three years after they appear. Sometimes a bank may have been in existence many years, and have reached a great size, without grass growing on it. The measures suggested could only prove efficacious in exceptional circumstances, and though at first sight they appear inexpensive, they would, if followed up, entail very heavy expenditure. The groynes may prove very valuable in the Hline or Nawoon rivers where the body of water to be diverted is not great; but it is thought that for the Irrawaddy it will be more economical in the end to let it work out and exhaust its effort when it threatens the bank."

Seductive nature of proposed river regulating works.

204. The writer can now only endorse and emphasize these recommendations, which are, perhaps, the most valuable he has had to offer. The prospect of diverting the river is most seductive and he has himself often been tempted to undertake it. No other phase of experience on the embankment works has caused him so much anxiety or study; and considerable pressure has been brought to bear to try such means, both at Myanoung, at Henzada and at Zaloon. The great sandbank still exists in front of Henzada (1) but the river has thrown in a small arm, several hundred feet wide, which although favorable to the town in opening up a channel for traffic, has acted with great caprice, and cut off large slices of the town front. It has at different times been possible to stop this channel and so prevent further action. This would have obstructed commerce. Then the openings have changed about, now further up, now lower down, so that any temporary works would have been flanked. The civil officers have repeatedly desired a channel to be cut across a neck of the sandbank, some 30 feet deep; and the people have offered to subscribe funds. The writer has persistently declined to recommend this being done; as, in the first place, he felt sure it would have been filled in its upper entrance like most such streams, and be so far useless; or, if by any chance it were successful it would divert the channel directly on to the town front and wash a portion away. This last event which was threatened for two or three years, has now occurred of itself (in 1878) and a portion of the town with a quarter of a mile of the embankment and several houses, have disappeared into the river; while a new channel is opening out still further up as a continuation of the Sarawa curve, promising next year to bring the main channel of the Irrawaddy back to Henzada where it has not been

(1.)—It is now being rapidly swept away by the river (July 1879) and for the first time in many years the main channel approaches the right bank at Henzada.

for 20 years. No more hopeless task could be imagined than trying to completely control all these movements.

Past experiments.

205. The writer feels bound to dwell at length on this question, as none seems more debateable from the opposite site; and as, with the exception of General Fraser, he is in total opposition to almost all the Engineers who have been practically connected with the works. And it is more than probable that any change of executive control will bring with it changes on this point. The temptation to interfere with the river is almost irresistible, and occasions are always present. Mr. Hallett, during his charge of the works, while the writer was away in Europe in 1873-75, made attempts in this direction; one in particular on the Nawoon near Ngathain-gyoung where great facility was offered. A canal was cut and two or three spurs run out from the bank. The river simply took no notice of them, and the spurs disappeared, while the channel, across a narrow neck of land, has exercised no influence. The project was well considered, but not on a sufficient scale. During two months absence in 1877, an Assistant who was left in charge of the works tried a somewhat costly experiment by putting in a groyne or two in front of Kanoung, the only result being the throwing into the river of a sum of money intended for the maintenance of the works. The idea and the intention were good; but in present circumstances it should be laid down as a cardinal principle that no protective works of this kind should be attempted, until a well devised scheme is sanctioned to include great lengths of the river channel, which will cost enormous sums of money; and which can only be justified when interests of greater moment than any now threatened are involved.

Causes of these lateral variations of the channel.

206. The grounds upon which this recommendation are based will be best understood when the causes on which this lateral variation of the river's course depend are investigated. It will be seen that they are closely interdependent with the vertical variations of the river channel. An account of the views entertained on this subject, and the principal facts relating to the variations in height of the banks and bed, and of the water surface is thus necessitated, and will be included in the next section.

SECTION VIII.

On the co-relation between the lateral and the vertical variations of rivers.

Mr. Fergusson on the lateral variations of rivers.

207. Mr. James Fergusson, whose pre-eminent services to architecture have placed him in the highest rank as an investigator, lived for some 5 years on the banks of the Bramaputra in Assam, and studied carefully the variations of that river, which proceed there on a colossal scale. In a paper read before the Geological Society in 1863 (1) he gave the result of his studies upon the united delta of that river and the Ganges, with an account of the recent changes there. He describes the lateral variations of the main channels of the rivers in their lower courses, but precedes the description by the following statement of the general principles upon which they depend. "Oscillation of rivers.—Before describing the actual phenomena, it may be necessary to call attention to certain principles, not very recondite, perhaps, but indispensible to clear understanding of what is to follow. The first of these is:—All rivers oscillate in curves, whose extent is directly proportionate to the quantity of water flowing through the rivers. An inspection of any good map is sufficient to prove the general correctness of this dictum, but its consequences have been strangely overlooked both by engineers and potamologists. Without attempting to enter into the theory of the question it may be sufficient for the present to state, in illustration, that the action of rivers appears to be the exact converse of that of the pendulum. The pendulum is a body in stable equilibrium, whose natural condition is that of rest, and, being once disturbed, it seeks to regain that position; but, the original force remaining, it would go on oscillating for ever if we could abstract all the natural conditions of friction, resistence of the atmosphere &c."

Statement of Principles regulating such variations.

"A river on the contrary is a body of water in unstable equilibrium, whose normal condition is that of motion down an inclined plane; and, if we could in like manner abstract all the natural conditions of inequality of surface or of soil, it would flow continuously in a straight line; but any obstruction or inequality whatever naturally induces an oscillation, and, the action being continuous, the effects are cumulative, as those in the pendulum are dis-cumulative; and the oscillation goes on increasing till it reaches the mean between the force of gravity tending to draw it in a straight line, and the force due to the obstruction tending to give it a direction at right angles to the former. If this be so, it will immediately be perceived that the extent or radius of the curves will be directly proportioned to the slope of the bed of the river. If, for instance, a river were flowing down a regular slope, through a perfectly homogeneous soil, with a fall of say, 10 feet per mile, or 1 in 500, the curves would be so extended as to appear merely a straight line on the map. With a fall of 1 foot per mile, the radius of the curve is, as nearly as I can ascertain, double that of a river with a fall of 6 inches; and when the fall is about 3 inches per mile, the direct and tangential forces so nearly balance one another that the curves are practically semicircles. In the latter case the chord of the curve is practically four times the width of the river. Thus a river 1,000 feet wide would oscillate once in 4,000 feet in the general direction of its course and the extent of its curve measured along the general direction of the stream, is a little more than 6,000 feet. Between a fall of 6 inches and 1 foot per mile, the oscillation is, apparently, once in about six times the width; above a foot it rises to one in ten or twelve,

(1.)—Fergusson Mr. James F. R. S. On recent changes in the Delta of the Ganges 1863.

above which it is extremely difficult to find examples, uninfluenced by natural obstructions. It need hardly be remarked that these observations apply to rivers when their beds are full, which is the only time when they are shaping their courses."

"There are a number of other consequences flowing from these, to which I shall not allude here, as they have no direct bearing on the subject in hand though it would be extremely interesting if they were observed and tabulated; for not only would these tables enable any one on inspecting a map to calculate approximately the shape of a country, and to estimate the relative importance of every river there delineated, but they would enable the engineers to regulate their courses, and the statistician to predict the result of the changes he sees taking place. To make this clearer, let me take one example. The Austrian engineers have of late years spent enormous sums of money in the attempt to straighten the course of the Danube by cutting off its lateral branches. This has been done by embanking across their mouths with dykes of fascines and piles. For a time this resists, and might resist so long as the river finds some other place where it can readjust its curvature; but, as these are stopped one after the other, it bursts through the barriers and resumes its own course. The fact is, the Austrian engineers are trying to make the whole body of water flow in curves due only to a portion, and they have hitherto, as might be expected, found this impossible. Had they taken the trouble to calculate the curve due to the whole body a few simple groynes would have sufficed for all their purposes."

Modification of Mr. Fergusson's principles proposed.

208. This extract brings prominently forward some principles which experience fully sustains, while others appear to require modification according to the part of the river considered. Thus it seems incontestable that there is a direct connection between the extent of the curves in which river channels oscillate and the mass of the water in flood discharge. Mr. Fergusson adduces instances in support of his statement regarding the ratio of the curve to the slope of the river; but they would seem to require a larger number of examples to confirm it. Two out of the four instances adduced by him almost reverse the rule laid down, that the radius of the curve, or of the oscillation is directly proportioned to the surface fall of the river. We know that all rivers without exception have higher falls at their sources than lower down; the rate of fall continually diminishing to the sea. The Ganges, by a table he gives, has from Allahabad downwards on an average of 6 lengths of somewhat over 100 miles each, curves whose lengths of oscillation are given by the figures 3·7; 4; 5; 7; 9·5; and 9; while two succeeding lengths of 44 and 36 miles have curves of 5 and 4 miles length of oscillation. The Bhagaruttee has on succeeding lengths of 120; 30 and 42 miles, curves whose lengths of oscillation are 1·5; 2·5 and 3 miles respectively in length. It would thus seem as though the length of curve, and with it the greater gentleness of action by the river, increased as the fall diminished. The present curves on the Irrawaddy follow this rule approximately. The two curves at Kyangheen have each a radius of about $1\frac{1}{2}$ miles. The Monyo and Pouknoo curves are $1\frac{3}{4}$ and $2\frac{1}{8}$th miles radius; but are followed by two smaller curves of $1\frac{1}{4}$ miles radius near Thambyading before the wider sweeping curve of $3\frac{1}{8}$ miles radius is met with near Zaloon.

Alteration of principle of action in different parts of a river.

209. Again there can be no doubt that in the bed of deposit of a river, such as the combined Ganges and Bramaputra Delta, to which Mr. Fergusson's studies refer, the main channel is in a state of unstable equilibrium, the very opposite of that of a pendulum. When an obstruction is sufficiently powerful to divert the channel from its course, it often diverges widely, roaming all over the bed of deposit. Several such changes are known to have occurred on the Bramaputra main channel in the Delta. But in the principal trunk of the river, well above the bed of deposit, and beneath the gullies of its more important contributaries, and where the deposit and the erosion compensate each

other, the channel is in more stable equilibrium; and, though, like a heavy pendulum or the Logan Rock, it is very easily moved slightly from any given position, any attempt to move it further vastly increases in difficulty; and it continually tends to move back to its former course. It is this facility of moving the river course slightly when conditions are favorable, which has led engineers to believe in the possibility of permanently controlling rivers by inadequate means throughout their whole course. The insuperable difficulties of doing this effectually arise from the fact that it is a normal condition of the river to erode its banks and transpose large masses of earth in its channel, and no defensive works which do not provide a sufficient area of ground for the river to operate upon can be considered permanent.

Gravity the cause of the curve forming erosions.

210. Mr. Fergusson recognizes this implicity in his statement of the fact that rivers flowing through alluvial deposits do oscillate in curves; and, if it could only be ascertained what are the principal facts upon which the oscillatory or excavating action depends, a great advance would be made in satisfying the practical requirements of foretelling approximately the general limits of such oscillations, and in providing for them. A further slight divergence from Mr. Fergusson's views seems to the writer requisite to explain some of the phenomena met with. On examining any single curve or set of curves from its incipient stage to the period of its final disappearance on the river channel, it appears that the river course actually seeks out obstructions as if it were for the purpose of removing them. The energy derived from gravity needs to exhaust itself; and, so far from this force struggling to keep the river in a straight line, it is gravity which causes the water carried in the channel to attack the banks, whose apparent endeavours are to keep the river straight; and it is only with their yielding to the continuous and uncontrollable excavating action, that the river takes a sinuous form. The erosion only ceases when the energy locally developed in the flowing water is not in excess of that required to cause its downward flow in the channel.

The energy developed by gravity is distributed into internal and external work.

211. We are thus again brought face to face with the fact that rivers have at times a surplus energy developed in them beyond what is required for the mere flow of the water down the channel to the sea, and that while the total energy generated on an unvarying discharge in a determinate portion of a river channel, like that of the Irrawaddy from Saiktha to Yandoon, is a fixed quantity, of which a definite part can be utilized on the internal work of the flowing water, the remainder, which is equally definite and unvarying, must have external work provided for it to do. This external work, as before explained, consists in rolling sediment along the floor of the channel, in excavation of the islands and banks met with in its course, and in the transport of silt by the water. It follows from this that, if at different parts of its course the energy developed varies, while that used up in the internal work of causing simple flow remains the same, the amount of energy disposable for external work must also vary. In a single channel of similar dimensions and form the chief cause of the flow of the water and the principal index of the total energy developed is found in the surface fall of the river.

Levellings along river banks, and in connection with mean sea level.

212. A series of levels have been taken throughout the upper delta, on both banks of the Irrawaddy, and on numerous lines across the country on both sides as well as down the left bank of the Nawoon river. These have been connected by check lines of level brought down from Prome to Myanoung by Colonel Stoddard in 1868, and the Prome datum has since been connected with mean sea level at Rangoon. It is not known with what degree of accuracy the railway levels were carried from Rangoon to Prome over a length of 160 miles; a distance on which fairly good levelling might admit an error of two or three feet. The check levels from Prome to Myanoung on 50 miles differ by about one foot. There may thus be an error of a few feet in the height of the embankment levels above the mean sea datum. But the

levels taken on the right bank of the river from Saiktha southwards to Henzada and Zaloon and also down the Nawoon line have been carefully checked with the utmost precaution, and can be relied on as showing the differences of level at the various points amongst themselves with close accuracy. As the river bank varies in height, owing to its numerous small irregularities, and does not present an even surface throughout, it is difficult to fix between any two nearly contiguous points the exact surface fall of the land. And the different flood surfaces of the water differ from one another. But by taking one of these as a datum line, comparisons can be made conveniently between the levels of the land and of the various flood surfaces; and of the various low water levels of the river in different parts of the channel. The high flood level of the year 1875 has been chosen as the datum line for the Irrawaddy main channel; and with it have been connected fixed points, called for convenience of reference, 40 feet, of all the river gauges from Saiktha to Donabyoo, the lowest station to which the embankments have yet reached. On the Nawoon side the 1875 flood was also chosen as a datum in that year, but the 1876 flood showed such an excess of height in the lower part of the river that the highest rise of river surface, whether of 1875 or of 1876 was adopted for the Nawoon; and to this datum all the gauges have had their 40 foot marks adapted. The 1877 flood rose above these datum lines both on the Irrawaddy and on the Nawoon; but no further change of gauge or datum was expedient.

High flood datum line. Flood of 1875.

213. The heights above the mean sea level of the surface of the 1868, 1871, 1875, and 1877 floods at different stations of the Irrawaddy, from Saiktha southwards, are given in the following table with the distances by river and by bank from Saiktha, and by river from the sea.

Heights of Floods and Low-water surface above mean sea level.

Table 21.

Stations.	Distance from Saiktha by bank.	Distance from Saiktha by river.	Distance from sea by China Bukeer river.	Flood Surface height above mean sea level.				Low water height above M. S. L. 1877.
				1868.	1871.	1875.	1877.	
Saiktha ...	0	0	230	...	...	77·86	79·74	39·42
Myanoung ...	13	15·5	214·5	68·47	70·15	70·91	71·87	30·18
Kanoung ...	20·0	22·7	207·3	66·19	67·23	68·07	...	...
Shwé-gyeen ...	31	35	195	59·55	60·50	61·34	62·09	20·01
Nyoungyo ...	45	51	179	52·07	53·77 (?)	53·77	54·10	14·44
Loodanzoo ...	50	63·5	166·5	...	49·02 (?)	...	...	...
Nawoon (1) ...	61·0	72·0	158	...	44·76	45·7	...	...
Henzada ...	69	84	146	41·19	42·48	43·48	43·78	5·46
Zaloon ...	86·5	101	129	...	35·47	35·99	36·41	2·99
Donabyo ...	112·0	130	100	...	..	24·47	24·43	0·00 (?)
Setkaw ...	125	144	86	...	18·89	19·00	...	0·00 (?)
Baudee (2) ...	138	165	...	...	...	10·99	...	0·00 (?)

214. The extreme low water levels at Donabyoo and Saiktha appear to be slightly below mean sea level, which, with the nearest distance at 100 miles from the sea, at the former place, is improbable. It is therefore likely that some error of from 2 to 4 feet in the absolute height above mean sea level, has been transferred in the whole course of the levels from Rangoon to Prome,

Probable error in height above datum.

(1.)—The Nawoon reading is taken about 1 mile down entrance of Nawoon river.
(2.)—Baudee is 13½ miles down the Pantanaw river, opposite Pantanaw.

and thence again to Donabyo, over a course of nearly 400 miles of levels. These heights are therefore subject to correction, as well as those to be given for the Nawoon.

Reasons for taking the 1875 Flood as a datum.

215. The high flood surface of 1871 presents the advantage of being generally more nearly parallel to the land than those of the greater flood of 1875 and 1877; but the 1875 one has the advantage of being more accurately noted at Saiktha, at Nyoungyo and at Donabyoo. At Setkaw and Baudee marks pointed out on house posts have been levelled to, and may slightly err. It is thus a more convenient one to take for illustration and reference. The low-water for 1877 was generally the lowest recorded at all stations except at Saiktha, where the changes in the lateral curvature of the river have been accompanied with vertical changes in its bed.

Estimate of the energy derived from gravity in the flow of water.

216. In order to form a conception of the natural forces with which the Engineer who undertakes to regulate and control the Irrawaddy will have to deal, a few of the available figures may be considered. At the height of the 1875 flood on the 17th August, no less than 4600 million tons of water passed the head of the delta at Saiktha in a single day. Its average velocity was about 7·5 feet per second. The energy or living force contained in that moving mass is represented by the well known formula $M V^2$ where M the mass is the 4600 million tons of water and the velocity V is 7·5 feet per second. As this velocity is little short of that which would be generated by a free fall of one foot the energy actually residing in that flowing mass is equal to 4600 million foot tons; or the equivalent to that number of tons raised one foot high. Expressed in horse-power, and for simplicity taking one horse power as 15 tons raised one foot high per minute, we have here an amount of work stored up above that which 200,000 horse-power continually exercised for a day of 24 hours could do. But this mass of water has to fall to the mean sea level, and that portion of it running in the channel between Saiktha and Setkaw has a mean fall which can be approximately estimated as follows. The surface fall of the high flood of 1875 was 58·86 feet from Saiktha to Setkaw. The low water surface between the two places falls about 39·42 feet. The actual fall of the mass of water passing Saiktha in this distance, which is about 140 miles on the main channel, is the fall of the centre of gravity of the mass between the two places. This may be taken to be approximately half the sum of the flood and the low water fall, as several bars exist in the river to below Setkaw, which regulate the depth of discharge at all seasons. Thus the fall on this portion of channel would be about 49 feet on an average for the mass; and the amount of energy generated in its fall from Saiktha to Setkaw was over that of 10 million horse power at work for one day. This energy is the dynamic head which causes the flow of the water, and which is wholly consumed in doing work in the passage of the water from the higher to the lower level. It is distinguishable from the energy $M V^2$ residing in the flowing water at any given time, and which is only utilized finally in the portion of the delta where all action of gravity in promoting the flow has ceased. The whole of the water passed down the channel every year falls in the same distance somewhat over 40 feet, and as the yearly average discharge is about 425,000 million tons, all of which employs some portion of the energy developed in its fall in moving and transporting the alluvial matter of its banks and bed, it is of importance to form an idea of the distribution of this energy into the parts required for the internal work of flow and into the external work done on the channel. The authors of the Mississippi Report have expressly recognized the distinction, but confine themselves to embodying in their formula for river discharge, that portion only of the energy consumed in internal work. Any attempt to accurately determine the two amounts would, in present circumstances, be vain, and all that is now aimed at is to enable the great magnitude of these forces to be realized.

217. To show the nature of the work performed by water in its downward flow in streams a few experiments of M. Bazin may be noticed. An artificial channel, somewhat under 2 metres (6·48 feet) was prepared, and lined successively with different materials presenting varied degrees of roughness. In each stage of the changes exactly equal quantities of water were passed down the channel, and all the attendant and resulting conditions were accurately noted. The materials used as lining were :—smooth cement, regular brickwork, planed boarding, small gravel, and large gravel. In the series of the experiments on the part of the channel which had a slope of 0·0049, a mass of water equal to 1·236 cubic metres per second was discharged; and though all the conditions, except the necessary changes of the thickness of lining on the channel, were identical, it was found that the following differences resulted in the flow :—

Nature of the work performed in the flow of water. M. Bazin's experiments.

1·236 cubic metres of water per second in channel of 0·0049 slope has with lining of

	Cement.	Brickwork.	Boards.	Small Gravel.	Rough Gravel
velocity	2·460	2·047	2·179	1·697	1·493 metres per second
area of cross section	0·525	0·604	0·567	0·728	0·828 square metres

Here the influence of the lining manifests itself in changing both velocities and areas. A further change shown was in increasing very much the relative velocities of the fillets or contiguous layers of the water with the rougher linings of channel. The amount of energy generated and used up in the internal work of the flow was the same in both cases; but had the object been to determine what respective amounts of energy would be required to carry the water at a constant speed down the different linings of the channel it would have been seen that a much smaller amount of work is performed on the water by the smoother linings than by the rougher. The slope of the channel gives directly the proportion of energy developed. On another part of the same channel a slope of 0·0059 was given instead of that of 0·0049 as before. It was then found that with a lining of boards the 1·238 C. metres of water acquired a velocity of 2·349 metres per second; being 0·111 metres less than that in the cement lining on the slope which had nearly one-fifth less fall; and where probably $\frac{1}{4}$th less energy would be used in giving the same velocity of flow. When the fall is increased the new energy developed must be utilized either in increasing the velocity, or in acting upon the channel.

Differences in the internal work of flow.

218. Thus if the channel of the Irrawaddy from Saiktha to Setkaw were perfectly straight (about 100 miles in length) and composed of hard unyielding materials of smooth cement, a very much smaller fall than that of from 40 to 50 feet above noticed would suffice to carry the water at the velocities now attained. If the material were changed to sand or alluvion such as is now found in the river, but so fixed that the water could not attack it, the fall required to convey the water would still be much smaller than that now available. The lengthening out of the channel to 140 miles by bends and curves gives additional work to be performed by the water; but with an unyielding channel lining there would be still a much smaller amount of work utilized at present velocities than is now required. Hydraulic science does not at present permit any exact or even approximate discrimination of these several quantities of work; but there can be no doubt whatever that they are distinct and determinate amongst themselves; and that no increase or diminution can be made upon the one, while the dynamic head is invariable, without a corresponding inverse change upon the others. If the present channel were lined throughout with banks of smooth stone or timber so as to facilitate the flow, at the same time that all further excavation of the banks were prevented, there would be, first, a vastly increased velocity of flow in the channel, followed by an excavation of the bed, the effects of which would be felt far up in the rock bound channel above Saiktha. Any partial

No regulative works can entirely remove the external work of the Irrawaddy discharge.

works of defence can only transfer the present action of the water upon the banks to other points not very remote. It would be absolutely impossible under present circumstances to regulate the whole channel of the Irrawaddy throughout its length in the soft alluvion of the Upper Delta so as to prevent any erosive action whatever; and though it may be advisable on some occasions to divert the local action from points of much importance, such work should only be undertaken after a careful consideration of the whole of the circumstances and the probable consequences of the change of the sphere of action.

No attempt at present regulative action advisable.

219. As matters now stand with regard to the whole of the embankment works and riverain interests, the writer strongly counsels nothing being done, or money expended with a view to interfere with the present river action, whether at Myanoung, Kanoung, Henzada or Zaloon; or with regard either to the opposite courses of cutting across the neck of the Thambyading bend as recommended by Mr. Bennett, Colonel Oliphant and Mr. Hallett, or of trying to regulate or delay the cutting across as recommended by the Mississippi engineers. Things are culminating to a crisis at this last mentioned part; and a catastrophe may result. But it is also likely that no great catastrophe will occur; and after the first turmoil and commotion on the bend cutting through, affairs will most probably settle down on a more secure basis than before.

Probable effect of the Thambyading cut-off.

220. Some of the results of the inevitable cut-off may be foretold. The fall of the high flood surface of 1875 from Nyoungyo to Henzada is, very accurately, 10·29 feet. The total distance by the main channel in 1877 was 33 miles. The surface fall, taken along the *thalweg,* is thus about 0·312 feet (3·74 inches) per mile. Of the total fall of 10¼ feet about 7 feet are required (by Mr. Hallett's level) between the 59th and 76½ miles of the channel, that is from one side of the neck of the bend to the other.

Changes in the length and slope of the river.

This distance of 17½ miles, within which the most intense eroding action occurs, consumes the work due to 7 feet of the fall at the rate of 0·400 feet per mile. In the other parts of this length of channel the erosion is comparatively small; the water flowing in tolerably straight reaches with a slope of 0·210 per mile. If we could be sure that this represents the true share of the work consumed in promoting the flow of the water, with the rolling of the sediment on the bottom, and the transport of the silt in the stream, the difference between 0·210 and 0·400 or 0·19 feet per mile would thus be the share of the fall devoted to excavating the banks. The total fall on the 144 miles of channel from Saiktha to Setkaw is 58·8 feet or 0·402 feet per mile, which would imply that nearly one half of the energy developed on the river water by gravity is used up and must be used up in displacing the banks and bed.

Process of the cut off forming.

221. The cut-off, when it first occurs, will give a fall of about 7 feet in a single mile. The phenomena of an event of this kind are described by Colonel Suter for the Mississippi, and similar records may be found for other rivers. The lower end of the creek or creeks will open out, the excavation will retrogress to the upper entrance; it will then balance and at length overcome the present deposit; and finally the whole creek will be scooped out with frightful rapidity and turbulence, and the whole body of the flood water will cut out the new main channel of the river with extreme violence. When the operation is complete the waters will rise 2 or 3 feet higher below the cut-off than before; and above it there will be a corresponding diminution. The whole surface of the river from Myanoung to the cut-off will, for equal discharges, be lower than it has been for many years. The cultivation on the high banks from opposite Myanoung southwards, which has been gradually submerged by the flood surface of the river rising with the lengthening out of the bend can

thus be resumed, and the towns of Mengyee, Yaygheen and Monyo, will develope a more active existence; while the flood level of the upper Hline Valley, which the villagers residing there declare to have been raised in consequence of the embankment works, will be (to them inexplicably) lowered. It will be extremely curious to see what the effect will be on the main channel in the reaches shortly above the cut-off. Will the inevitably greater activity of erosion determine the Monyo bend to take a sharper curve, or will the channel become straighter? In the former case there may be trouble for the Myanoung embankment about the 35th mile. But the whole action may pass down the river without touching the permanent bank, and speculation upon the matter is at present idle. Surveys should be made from time to time on this and other parts of the river.

Consequence to Henzada.

222. Below the cut-off the force of the water will be directed on to the immense sandbanks and islands now lying below the bend. These will protect Henzada for a long time, in all probability. Previous to the formation of the Thambyading bend, there does not appear to have been any great excavating action on the bank in front of the town, though there was much in 1854-57, when nearly half a mile of width of the river front was carried away, with pagodas, monasteries and houses. There are no traces of high banks near the town such as would have been left if the river had made former inroads on it. Such traces exist at Dooya a few miles south; and again south of Zaloon. It is probable that the greater erosion will be transferred much lower down, where the flood channel is wider. But the contingency must be contemplated of such an event happening as the town being again attacked. The best means of meeting the difficulty will be a partial retirement of the marginal embankment to a second line of road parallel to the river. If ever defensive works are adopted it should be on such an occasion as the one considered. They will be found to be of a more expensive nature than those suggested by Colonel Stoddard.

Policy of occasional retirements of embankment works.

223. If it be once accepted in principle that the complete regulation of the Irrawaddy in the Upper Delta is inexpedient or impracticable, and that it is only in the most extreme and exceptional cases, where large sums of money can be spent with advantage, that even occasional resort be had to defensive works, it is necessary to consider in what degree the embankments may be affected, and what policy should be consistently observed regarding them. It will be found that differences in the attendant circumstances justify changes in the principles and practice of the alignment of the embankments; and that while it is claimed that immense savings in first cost, increased strength and safety have been secured for the later built embankments on the borders of the Henzada plain by the adoption of a reduced minimum distance of retirement from the rivers edge, there are exceptional circumstances affecting the river near the Myanoung embankment which make it appear that the large minimum there given, of 500 feet retirement, by Colonel Short and Mr. Fennessey, was, in some respects wisely chosen. But also that the very circumstance which applies in this case is not found to exist in any other, and least of all in the same part of the river in so far as it affects the proposed Tharrawaddy embankment on the eastern side. The peculiar and exceptional circumstance alluded to is the operation of a natural principle known as Baer's law, after the distinguished St. Petersburgh Professor, lately deceased, who first called attention to its action upon river banks.

Baer's Law of river changes.

224. Pappus, who flourished about A.D. 380, demonstrated some of the properties of the curve described by a point passing from the vertex of a sphere to its equator while the sphere revolved under it. If the sphere revolves regularly while the point traverses its surface along a fixed plane passing through the axis of the sphere it meets gradually increasing circles in its course, and traces a spiral of double curvature on the face of the sphere. Farrel has shown that the winds blowing

from the poles to the equator of the earth take directions approaching this spiral form, a law now universally admitted in meteorology. Professor Baer showed that water flowing in a river with a north and south direction has a tendency to shape the course of the river on a similar curve. That is, rivers running like the Irrawaddy from north to south would under the operation of this law tend to excavate their western banks. It has been found in actual experience in rivers all over the world and in both hemispheres, that phenomena exist in the lateral motion of their courses which can only be explained on the assumption that this law is effective.

The westing of the Irrawaddy.

225. The writer called attention to the westing of the Irrawaddy in a part of its channel in his Report of April 1868. The law above mentioned was described and the mode of action explained. The increase in size of the parallels of latitude traversed by the particles of water on their southward course was noted, and the following figures given to show the actual distance travelled by the same particles from west to east with the daily revolution of the earth in the part of the channel affected :—

Latitude	diurnal velocity of earth's surface in miles.	increased distance traversed.
18°30′	23613·26	0
18°15′	23647·50	34·24
18° 0	23681·31	68·05
17°45	23714·66	101·40
17°30	23747·55	134·29

There is thus a difference in the actual velocity with which the particles of water are carried of 134 miles in their course from above Saiktha to Yandoon, the limits above taken. This increased velocity must be imparted to the water by the western bank of the river, and if the re-action between the water and earth of the bank is greater than the cohesive power of the bank can resist, this must yield and be eroded. In time some results would certainly be made manifest. It was then pointed out that the eroding action was greater on the western than on the eastern bank. This action has been continued and has increased to the present time on the bank from Kyangheen southward ; and the westerly tendency of the whole main channel above the Thambyading bend is in all respects most remarkable. While the fact cannot but be admitted for that portion of the river, it has been pointed out that the lateral motion of the channel alluded to appears only to have occurred within recent periods, and that if any such tendency had always been in operation at the same rate as now manifested the Irrrawaddy main channel would long before this have reached the base of the Arakan Yoma throughout its course to the sea. There is evidence of one channel of the river having followed that line much as the Nawoon does now; but there is none of the present main channel having varied beyond the present permanent bank. It may further be objected that no such variation exists in the channel to the south of the Thambyading bend where the tendencies eastward and westward appear equal. Both objections are well founded, and it is not easy to answer them. But it has clearly been proved that similar tendencies exist in similar circumstances on other rivers. And it will presently be shown that there has been a decided movement westwards of the main channel from Saiktha to Thambyading. Probably the tendency always existed, but never found occasion for exercise until the entire lifting of the river channel and flood surface consequent on the formation of the Thambyading bend came into operation. In this case the whole movement would have been principally comprised within the present century, a supposition confirmed by the very recent character of most of the deposits between the main channel and the eastern bank. If this is the true explanation, then with the cessation of the cause of the manifestation the action will cease. When the river channel above Thambyading is lowered as a consequence of the expected cut-off all further translation of the westerly tendency into actual results will cease. This result is likely to occur within from 5 to 8 years. In the meantime the actual progress of the channel westward can be accurately observed.

226. As a result of the attention directed to this question in 1868, orders were issued to measure from time to time the changes of the main channel of the river, particularly in the part near the Myanoung embankment. It was not found practicable to do this earlier than in the dry weather of 1870-71. Permanent marks were fixed on the edge of the embankment, at every quarter mile (or oftener); and straight lines cut through the jungle in convenient directions. Two short posts have been fixed to perpetuate the initial point and the direction of the measurement; but as, every season, the jungle grows thick and impervious except by cutting over most of the lines it is somewhat expensive to take the measurement. It has, however, been done at intervals of two years, except in 1873. Table 22 gives the measurements made up to 1877. All the lines are marked in the large scale plans. It is to be noted that from the fixed points at the base of the embankment each line is carried across all the intervening alluviums in the principal flood channel until the actual edge of the main channel is reached, and it is this alone, and not the permanent bank which is everywhere given.

Measurement of distances of main channel from Myanoung embankment.

No. 22.

Table showing changes in Irrawaddy main channels from the Patashin Choung to Loodauzoo.

MEASUREMENT TAKEN FROM EMBANKMENT TO RIVER BANK.

Along Embankt. mile.	In 1871.	In 1875.	April 1877.	Novr. 1877.	Less.	More.
0	531	522		517	14	
1/4	1706	1600				
1/2	3882	3610				
3/4	3307	3080		3026	281	
1	2657	2670				
1 1/4	1022	1012		922	100	
1 1/2	481	480		465	16	
1 3/4	438			436	2	
2	1464			1417	47	
2 1/4	1102	1092				
2 1/2	2368	2345				
2 3/4	1356	1323				
3	580	576				
3 1/4	602	575		560	42	
3 1/2	1211	1205				
3 3/4	5590	5585				
4	2660	2650	2540		120	
4 1/4	1525	1493	1460		65	
4 1/2	585	547	537	513	72	
4 3/4	474	330		268	206	
5	603	450	425	312	291	
5 1/4	650	580	540	441	209	
5 1/2	635	612	605	565	70	
5 3/4	746	648	645	627	119	
6	712	645		643	69	
6 1/4	1383		1375	1366	17	
6 1/2	737		730	730	7	
6 3/4	655		650	638	17	
7	582	582	580	563	19	
7 1/4	554	550	549	536	18	
7 1/2	500	493	492		8	
7 3/4	500	490	488	471	29	
8	585	570	569	550	35	
8 1/4	775	756	754	756	19	
8 1/2	758		743	729	29	
8 3/4	954		954	946	8	
9	914	900	890	900	14	
9 1/4	979	979	967	970	9	
9 1/2	1078	1010			68	
9 3/4	1005	995	995		10	
10	794	794	793	786	8	
10 1/4	589	554	555	525	64	
10 1/2	544	522	500	465	79	
10 3/4	682	606	580	519	163	
11	592	533	520	460	132	
11 1/4	652	650	530	499	153	
11 1/2	929	829		816	113	
11 3/4	798	769		717	81	
12	690	680	680	680	10	
12 1/2	664	598	594	575	89	
12 3/4	666	665	658	646	20	
13	766	746	740	737	29	

Along Embankt. mile.	In 1871.	In 1875.	April 1877.	Novr. 1877.	Less.	More.
1/4	961	950	945	944	17	
1/2	980	960	960	944	36	
3/4	996	980	978	970	26	
14	993	986	983	984	9	
1/4	1029		944	967	62	
1/2	931	930	914			
3/4	1206	1192	1175	1170	36	
15	1163			1054	109	
1/4	880	880	855	847	33	
1/2	924	820		855	69	
3/4	859	800		824	35	
16	800	780	770	767	33	
1/4	741	730	730	719	22	
1/2	751	734	733	738	13	
3/4	926	908		912	14	
17	970	960	960	965	5	
1/4	1212	1208	1187	1190	22	
1/2	1456	1448	1431		25	
3/4	1469	1445	1431		38	
18	1387	1343	1334		43	
1/4	1311	1273	1248		63	
1/2	1413	1395	1376		37	
3/4	1288	1245	1240		48	
19	1211	1196	960		251	
1/4	1013	1004	950		63	
1/2	1085	1075	995		90	
3/4	1096	1090	985		111	
20	910	910	905		5	
1/4	1058	1052	1041		17	
1/2	1013	1010	1005		8	
3/4	959	961	960	950	9	
21	949	948	946			
1/4	984	977	965	918	66	
1/2	950	942	940	920	30	
3/4	993	993	970	940	53	
22	1073	1052	1050		23	
1/4	985	980	960		25	
1/2	924	919	902	896	25	
3/4	956	950	940	914	42	
23	999	995	910	901	98	
1/4	922	918	840	823	99	
1/2	854	842	800	784	70	
3/4	948	923	882	862	86	
24	983	973	960	937	46	
1/4	1003	992	960	964	39	
1/2	1009	1000		947	62	
3/4	1013	1010	980	1000	13	
25	1047	1015		993	54	
1/4	1407	1287	1273	1272	135	
1/2	2231	2127	2112	2198	33	
3/4	3825	3621	3585	3500	325	
26	4675	4640		4508	167	

Along Embankt. mile.	In 1871.	In 1875.	April 1877.	Novr. 1877.	Less.	More.
1/4	6047	5997	5962	5685	362	
1/2	6363	6302	6285	5685	678	
3/4	7022	6805	6752	6397	625	
28	7048	7004		7064		16
1/4	7480					
1/2	7020					
3/4	4810			4878		68
29	5787	5753		5440	347	
1/2	6007	5787	5753		254	
30	7125	7125	7120	6858	267	
1/4	7844	7830	7825	6452	1392	
1/2	4748	4740	4732	4750		2
3/4	4478	4450	4435	4405	73	
31	4275	4174	4170	4208	67	
1/4	4353	4220	4215	4205	148	
1/2	4272	4170	4165	4190	82	
3/4	4127			4071	56	
32	4090	3984	3980	3907	183	
1/4	3973	3967	3958		15	
1/2	3664	3973	3967			303
3/4	3611	3644	3877			266
33	2830			2900		70
1/4	1747			1749		2
1/2	1125	1085		914	211	
3/4	504	500	500	504		
34	444	436	410	424	20	
1/4	382	365	354	370	12	
1/2	912		700	688	224	
3/4	1050	1000		969	81	
35	1063			1070		7
1/4	1272	1164	1135	1154	118	
1/2	1124	1292	1164	1155		31
3/4	946	1124	1145	1084		138
36	918	910	910	964		46
1/4	906	918	910	951		45
1/2	732		648	754		22
3/4	696	652	647	654	42	
37	792	674	655	667	125	
1/4	695	615	595	594	101	
1/2	357	274	265	261	96	
3/4	285	216	208	185	100	
38	481	360	334	303	178	
1/4	496	369	333	310	186	
1/2	538	497	476	450	88	
3/4	762	652	642	630	132	
39	1341	1145		1110	231	
1/4	6320	6235	6205	6221	99	
1/2	8053			7933	120	
3/4	9900	9900	9820	8350	1550	
40	9800	9630		7998	1802	
1/4	8396	8276	8265	8250	146	
1/2	8396					

Along Embankt. mile.	In 1871.	In 1875.	April 1877.	Novr. 1877.	Less.	More.
41		12,540	12,530	11,250	290	
		12,750	12,780	11,250	500	
		14,260	14,135	12,475	1785	
1/4	681	658	657	679	2	
1/2	475	480	480	480		5
3/4	650	650	649	650		
42	578	578	565	572	6	
1/4	700	685	685	700		
1/2	546	548	548	546		
3/4	700	678	678	700		
43	624	610	610	524	100	
1/4	760	750		684	76	
1/2	595	458				
3/4	495					
44						

Table 22 A.

Shewing measurements between Myanoung embankment and bank of Irrawaddy Main Channel in 1871 *and in* 1879.

Embkt. mile.	Distances.		Differences.		Embkt. mile.	Distances.		Differences.		Embkt. mile.	Distances.		Differences.		Embkt. mile.	Distances.		Differences.	
	1871.	1879.	1877.	1879.		1871.	1879.	1877.	1879.		1871.	1879.	1877.	1879.		1871.	1879.	1877.	1879.
4 ¼	1525	1480	...	− 45	¼	993	956	− 9	− 37	¾	854	796	− 70	− 58	½ ¾	912	697	−224	−215
½ ¾	585	515	− 72	− 70	½ ¾	1029	1136	− 62	+107	25	943	820	− 86	− 128		1050	1000	− 81	− 50
	474	250	−206	−224		931	1203	...	+272	¼	983	908	− 46	− 75	35	1063	1070	+ 7	− 7
5	603	290	−291	−313	15 ¼	1206	859	− 36	−347	½ ¾	1003	915	− 39	− 88	¼ ½ ¾	1272	1157	−118	−115
¼ ½ ¾	650	405	−209	−245	16	1163	832	−109	−331		1009	...	− 62	...		1124	1155	+ 31	+ 31
	635	560	− 70	− 75	½	880	564	− 38	−316		1013	910	− 13	− 103	¾	946	880	+138	− 66
	746	620	−119	−126	17	924	623	− 69	−301	26	1047	985	− 54	− 62	36	918	851	+ 46	− 67
6 ¼ ½ ¾	712	1330	− 69	+618		859	850	− 35	− 9	¼ ½ ¾	1407	1272	−135	−135		906	790	+ 45	−116
7 ⅛	1383	...	− 17	...		800	...	− 33	...		2231	2197	− 33	− 34	¼ ½ ¾	782	725	+ 22	− 7
⅛ ¼	737	...	− 7	...	½ ¾	741	555	− 22	−186		3825	3500	− 325	− 325		696	650	− 42	− 46
⅛ ¼	655	740	− 17	+ 85		751	470	− 13	−281	27	4675	4507	− 167	− 168	37	792	660	−125	−132
⅛ ¼	582	...	− 19	...	18	926	815	− 14	−111	¼ ½ ¾	6047	5685	− 362	− 362	¼ ½ ¾	695	525	−101	−170
¼ ½ ¾	554	580	− 18	+ 26	¼ ½ ¾	970	910	− 5	− 60		6363	5685	− 678	− 678		357	239	− 96	−118
	500	565	...	+ 65		1212	411	− 22	−301		7022	6397	− 625	− 625		285	140	−100	−145
8	500	470	− 29	− 30		1456	1265	...	−191	28	7048	7064	− 984	+ 16	38	481	260	−178	−221
¼	585	...	− 35	...	19	1469	1285	...	−184	¼ ½ ¾	7480	...	...	...	¼ ½ ¾	496	284	−186	−212
¼ ½ ¾	775	555	− 19	−220	¼ ½ ¾	1387	1320	...	− 67		7020	...	...	...		538	384	− 88	−154
	758	725	− 29	− 33		1311	1240	...	− 71		4810	4878	+ 68	+ 68		762	597	−132	−165
	954	934	− 8	− 20		1413	1450	...	+ 37	29	5787	5440	− 347	− 347	39	1341	1076	−231	−265
9	914	925	− 14	+ 11	20	1288	1226	...	− 62	½	6007	6223	...	+ 216	¼ ½ ¾	6820	5690	− 99	−630
¼	979	...	− 9	...		1211	1200	...	− 11	30	7125	6858	− 267	− 267		8053	7285	−120	−768
¼ ½ ¾	1078	1305	...	+227	¼ ½ ¾	1013	1056	...	− 43	¼	7844	6956	−1392	− 888		9900	7325	−1350	−2575
	1005	1145	...	+140		1085	1050	...	− 35	½ ¾	4748	7506	+ 2	+2758	40	9800	7580	−1302	−2220
10	794	849	− 8	+ 55	21	1096	1185	...	+ 89		4478	4405	− 73	− 73		8396	9915	−146	−481
¼	589	514	− 64	− 75	¼ ½ ¾	910	1000	...	+ 90	31	4275	4208	− 67	− 67		8396	8150	...	−246
¼ ½ ¾	544	448	− 79	−101		1058	1046	...	− 12	¼ ½ ¾	4353	4108	− 148	− 245		...	1145		
	682	485	−163	−197		1013	1040	...	− 27		4272	4090	− 82	− 182	41	...	11857		
11	592	635	−132	− 43	22	959	950	− 9	− 9		4127	3950	− 56	− 177	¼ ½ ¾	...	9225		
¼ ½ ¾	652	492	−153	−160	¼ ½ ¾	949	980	...	+ 31	32	4090	3950	− 183	− 140		681	694	− 2	+ 13
	929	635	−113	−294		984	918	− 66	− 66	¼ ½ ¾	3973	4009	...	− 36		475	500	+ 5	+ 25
	798	829	− 81	+ 31		950	920	− 30	− 30		3664	3050	...	− 614	42	650	699	...	+ 49
12	690	418	− 10	−272	23	993	932	− 53	− 61		3611	2152	...	−1459	¼ ½ ¾	578	608	− 6	+ 30
½ ¾	664	573	− 89	− 91	¼ ½ ¾	1073	755	...	−318	33	2830	2460	+ 70	− 370		700	720	...	+ 20
	666	671	− 20	+ 5		985	802	...	−183	¼ ½ ¾	1747	1050	+ 2	− 697		546	560	...	+ 14
13	766	657	− 29	−109		924	890	− 28	− 34		1125	959	− 211	− 166	43	700	700		
½ ¾	961	927	− 17	− 34	24	956	895	− 42	− 61		504	505	...	+ 7	½ ¾	624	620	−100	− 4
	980	983	− 36	+ 3	¼ ½	999	845	− 98	−154	34	444	420	− 20	− 24		760	153	− 76	−607
14	996	956	− 26	− 40		922	695	− 99	−227	¼	382	367	− 12	− 15	44	595	...		

227. This Table (No. 22) shows that there is a distinct cutting away of the western bank of the main channel almost all along the entire line. In only two places, the 32nd and 35th 36th miles is there any addition to the bank recorded. In a few lengths only a slight erosion is apparent particularly from the 7th to the 10th mile. Yet here it is most unmistakable. This portion extends from the lower half of Myanoung along the rocky ground to Kanoung. The hard nature of the subsoil protects it from rapid injury, but it shares in the general movement affecting the permanent bank for over 23 miles from the north of Myanoung to Kyangheen. The upper two or three miles of this receive the full force of the stream from the lower Kyangheen curve, and the intense erosion here is manifestly local. It has cut away in six years at the $4\frac{3}{4}$-$5\frac{1}{4}$ miles of the embankment from 200 to 250 feet of bank which cannot have been touched by the river for thousands of years. Lower down in front of Myanoung a hard sandstone rock crops out, underlying the alluvium. The upper strata have been removed, though very slowly, some 20 to 30 feet in 6 years; but this has necessitated the moving of the marginal embankment which stood on the edge of the bank. The 10th & 11th miles have lost but a slight amount, generally from 10 to 60 feet in the same period. The 21st mile has lost very little, mostly about 20 feet, but the erosion again increases when the channel ceases to hug the old permanent bank, and, what is remarkable, starts on an eastward bend with the force of the current generally away from the west bank. On the 27th mile 500 & 600 feet of this alluvial bank are lost. The 28th mile has escaped measurement, but the 29th has lost an average of 300 feet. The 30th & 31st have suffered though not exposed to a heavy current. The 32nd has increased, while the 33rd is stationary; and so practically is the 34th, while the 35th & 36th have received additions. The next two miles are exposed to the cutting action of a large curve of the river which appears to have eroded the bank steadily since 1868, as the distance of retirement is now only 185 feet where it must have been originally a minimum of 500 feet. Here, in 3 years more, if the excavation continues, the work must be removed further from the bank. The succeeding miles lie behind a great sandbank in the bight of the Pouknoo bend, which changes from local influences. (1)

Notice of the various erosions.

228. This westerly movement, whether it be due to general or to local causes or whether it has a temporal or permanent character, justifies on the part of Colonel Short the adoption of the large minimum distance of 500 feet as an experiment, and as one to be used in the absence of data deduced from a lengthened experience of the changes going on upon the river. It is in no spirit of criticism of his or his successors work that the question has been raised. It is solely with the view of calling attention to the expediency of a smaller distance being given to the later and to future works on the ground of economy and safety that this has been done. The vexed problem of the height to be given to embankments, however difficult it may be, is incomparably a less serious one than this of the river movement cutting away the banks. In the former case we have to deal with forces that are commensurable with human agencies; here they are indefinitely greater, and cannot be permanently controlled. The Myanoung embankment, notwithstanding this strange movement of the river channel westward, and the impact of the Kyangheen curve on the bank has not been endangered for the first 43 miles in any part of its length during 11 years; and is now only threatened at two points at the $4\frac{3}{4}$ and $37\frac{3}{4}$ miles, where the erosive action is most intense. It might at all other parts have been much nearer the river, and its first cost have thus been reduced to $\frac{1}{3}$rd of what it actually has been. Financially, the work is re-

A large mininum distance from edge of river to embankment advisable at first.

The Myanoung embankment retirement.

(1.)—A further measurement has been made in March 1879, of the distances of the rivers bank from the embankment; and the result is embodied in the subjoined Table 22 A. In cutting, action has increased on the 4th and 5th miles, but not greatly. The 9th mile has received an accession; but from the 10th to the 20th, from the 23rd to the 26th, and from the 37th to the 40th miles, the progress westwards of the main channel appears continuous, The embankment is as yet nowhere endangered; but the $37\frac{3}{4}$ mile will require careful attention during the next two years.

ported as a failure. This would have been avoided, and some breaches due to weakness prevented if a minimum retired distance of 200 feet and a maximum of 500 had been observed in its construction. But while all the conditions of the movement of the river were unknown, larger allowances had to be made; and even now, under certain aspects, admitted by the Government, the work can be called a success in every respect.

Success of the Henzada embankment due to small retirement.

229. The Henzada embankment has not had any such general movement of the river channel to contend with; but has had to be retired from the position it was originally built in at different points. As before explained, through taking advantage of the high ground near the bank, 123 miles have been constructed at an average cost of 8,400 Rs. per mile instead of over 20,000 Rs. as on the older works more removed from the edge; and as a first consequence of this a very much smaller expenditure of money has secured protection to over 700 square miles of land; and the returns in the few years of its existence, and restricted solely to a land tax of about 1½ Rs. per acre for land wholly reclaimed, and to 4 annas for land protected, has paid interest and profit not only on its own first cost, but on that of all the other unprofitable works in addition. This result is one worth securing. And the only breach on the new works on the Irrawaddy side that has yet occurred took place in 1877 at a part which had been retired beyond the average distance to avoid erosion there threatening. This erosion was in the apex of the large curve which is now travelling southwards towards Zaloon. It has necessitated three several retirements of the line of embankment in 7 years, the last one being now made (1879); but the whole of these retirements extend over a length of only 3 miles and are made at a total cost of 40,000 Rs. Another slight retirement was made in 1874 at the 34th mile, where a small branch of the river re-opened suddenly, and cut away a part of the bank, the cost of this was 4,300 Rs. As the river ceases operating at one spot the action passes on to another, leaving a moderately high bank ready to receive another marginal embankment; the new bank, however, not being so high as it would have been if the water had been allowed to flow freely over it to the interior. The retired lines, after all danger of erosion has ceased might be safely abandoned or kept only as reserve works, and new light embankments be carried on the highest ground in front of them. As they stand, they are not so safe as the smaller works, and leave out often good ground where it is most valuable for houses and villages, just on the river's edge.

Government of India recommendation to resort to river training works.

230. When the retirement at Doungyee above Zaloon was first proposed in 1872 by the writer, the Government of India, in sanctioning the work commented on the proposal in the following terms: (Extract of para. 2 from P. W. D., letter No. 634 I, dated 1st August 1872.) "In conveying this sanction I am to remark, that in many cases, in delta countries, it has not been found more economical to erect retired lines of embankment, in preference to undertaking works for the diversion of the stream from the rivers bank. In retiring embankments it frequently happens, and in regular delta regions always is found that lower ground has necessarily to be occupied and that the embankment has consequently to be raised higher. A greater depth of water, as well as a stronger current acts againsts it in floods, and thus the embankment is exposed to greater trial, its stability endangered, and if an accident does take place, the damage to the country is greatly increased. Both the state and the people thereby sustaining greater losses inasmuch as the volume of water let loose into the country is by so much the greater. It has been found by experience in such localities, cheaper in the long run, to train a delta river than to let it have its own way. In Burma where wood is so cheap, pile and brushwood groynes ought to be very inexpensive, and these, where judiciously employed, have been found sufficient to ward off erosion and divert a river from setting on its banks. These observations should be borne in mind when dealing with the embankment in Burma."

231. These plans of protection have already been fully considered so far as anything short of the actual carrying out of such projects on the Irrawaddy can serve. The cost could not be determined even approximately. If such measures could be made efficacious the Mississippi Engineers would not have to record the losses noted in the following extract from the Report of the Commission of 1875 before referred to. In the State of Louisiana "in the eight years between October 1866, and October 1874, no less than 107·5 miles of levee caved into the Mississippi in that State alone, the total length of levees being about 800 miles." The Commission nevertheless recommend resort to experiments with defensive works such as wing jetties, revetment by hurdles, brush, or stone &c. In a note they say "A small pile jetty filled in with earth once stopped a dangerous caving which threatened to carry Natchez-under-the-Hill into the river. The success of the brush and stone rivetment near St. Joseph Missouri is well known, *but the cost was very great.*" To bring the matter to a final issue as regards the Irrawaddy; there is a comparatively slight erosion continually going on at Kemendine, a suburb of Rangoon. It is carrying away the foreshore, with piers and mills. Attempts have been made to stop this under the guidance of engineers resident in Rangoon. The great expense and the non-success of the works in preventing the erosion, which does not extend over half a mile or so, are notorious. If with the engineering talent and the abundant resources available the interests involved cannot be secured from danger on such a comparitively small scale how can it be hoped to apply regulative works successfully on the immense length of course of the Irrawaddy?

Not at present advisable on financial grounds.

232. The evils of excessive retirement on the other hand are admitted; and nothing could be worse than a state of things where the embankments were wholly removed from the high natural embankment offered by the river itself, and were everywhere retired to the low bottom lands of the country behind. The few miles, not over 15 altogether, on the Henzada embankment where such retirement has been found necessary, in carrying it across the low necks of bends &c. have caused more anxiety and loss, than all the remainder of the work. The first cost also has been a heavy charge on the rest: and if it is ever necessary to resort to extensive retirements, such as to change the whole character of the work; or if it be decided to adopt defensive measures systematically and persistently, an immensely increased establishment will be required; with so vastly increased an expenditure for maintenance that the works could never be remunerative. Happily, from the experience of the last ten years, there is no likelihood of any extensive resort to either means. The cases so far have been few, and of small extent. And even with these a third alternative is open. This was stated clearly in the writer's Report of 1870 on these works. After describing the two systems of the marginal and the greatly retired embankments of Colonel Short the Report states "A middle course has been chosen between these two. By keeping on the high ground of the permanent bank, at a sufficient distance from the edge (200 feet has been chosen as a minimum) the embankment can be made almost as cheaply as the marginal works, while it will avoid the risk of being breached through slight abrasion of the banks. It will be retired a little, the maximum distance to be 400 feet whenever there appears danger of the permanent bank being attacked. *If the danger is imminent, and the cutting away likely to be great, the embankment will not be constructed at that part until the permanent bank is reformed and raised to its former level.* This will leave the place exposed to the floods; but when the whole area is protected from the inundation, and the remainder of the edge embanked, the evil will be quite local, the flood water passing over will be carried away to the drainage streams, and the silt will in a manner repair the damage caused. As a great portion of the permanent bank is protected by islands and sandbanks in front, it is probable that not more than two or three miles out of the 160 will ever at one time be liable to this action, and possibly

Embankments generally retired are dangerous and expensive.

A third alternative open, To allow the river free play.

many years may pass without it being incurred at all. At the worst the cultivators can always be forewarned so that they need not sow rice, and the rich river silt will permit a dry weather crop of cotton or other plants to be sown when the floods go down."

In some cases this course alone is expedient.

233 This proposition is one which, at first sight, it seems difficult to believe can ever be seriously considered. It affirms that a better plan than either retiring the embankment or protecting the banks when these are threatened would be to do neither; but just to allow the river flood to pass over the bank as it now does from Loodauzoo to Thambyading, inundating the country in the rear, and at the same time forming new elevated banks on the low ground. Where no cultivation has yet been introduced, as in the locality named, this is the only possible resource, just to let the river and the land alone until the movement exhausts itself; and if ever a new bend like that at Thambyading commences to form, even at a highly cultivated part, there does not seem to the writer any other plan open than, after deferring the calamity as long as possible, to abandon the neighbourhood and leave the river free play. All expedients and palliations for the evil should, of course, be tried, provided a limit be fixed to the extreme cost of the experiments; but this policy of abandonment of the ground for a greater or less time must be distinctly contemplated as the final one to be recurred to in such a case. How would it do to recur to this means in other more ordinary contingencies? There are parts of the embankment line where it will never be required even to consider it; such for instance as the whole Nawoon line, where the vagaries of the river are on a small scale and within very mild limits; and can be met by protective works or by retirements. And there are others where the proposition must be absolutely excluded at any cost. Thus the part of the work executed from Colonel Short's designs, the Flank Myanoung Embankment, is the key, as he says, to the whole of that work. Any flood water getting free course through this would damage the whole Myanoung plain, and render the greater part of it unproductive. Similarly it would seem that the upper portion of the Henzada Embankment would, if left for two or three seasons with open breaches, cause excessive loss. But there are a large number of drainage channels scattered over all this region, old arms of the river, often 200 to 400 feet wide, now occupied by slowly moving drainage water, but capable of carrying off large masses of water from the river if this reached them. If the river makes a temporary set against the bank on a comparatively small scale, as has occurred above Zaloon, what would be the result of leaving the portion open to the river flood for a season? Having regard only to purely physical considerations this would be the very best thing to be done. The water passing over brings with it abundant silt with which it forms new banks as fast as it cuts away the old, and a new rim is provided for the shallow interior basin, on which fresh embankments can be raised. Under this aspect the operation is all that can be desired. But in the meantime a part of the country will be inundated.

The Zaloon breach.

234. The case cited, that of Zaloon, gives the required example. In 1877, the retired work was breached, and the water poured through for 3 months. The breach was several hundred feet wide (about 600 at least) and permitted the large portion of the spill from about 1½ miles of the bank to go through. Mr. de la Courneuve, Revenue officer, examined the damage while the water was on the ground. He found the water flowing rapidly away at some distance inland. His remarks are pertinent and merit quotation. "It would be only natural to suppose that the velocity of the water after having spread itself over a vast area of country would have diminished, but strange to say, such is not the case. The river bank here is characteristic of every river and stream that has come under my notice in Burma. The frequent overflows of the river appear to have left a deposit of silt on the banks, which has in the course of time raised them considerably higher than the country inland. Hence, the reason of the increasead velocity of the current I experienced up to a certain point

in the plains, where in some places the water obtained a velocity of not less than seven miles an hour. A proof of this theory may be seen all along the embankment. Elevations caused by the spill water of the river will be frequently met with. The people at Ma-oo-bin cut through this high land on the river bank and admit the water into the lands at the back, thus forming fisheries and silting up the swamps to such an extent that they are enabled to extend their cultivation from the river bank interiorwards year by year." Mr. Courneuve went over the whole of the damaged area, and though his account of the velocity of the water seems exaggerated, as it had hardly seven miles per hour velocity in the breach, there is no doubt but that it flows away rapidly through the interior. His estimate of the damage caused was 5,430 acres of crops finally destroyed. This, it must be remembered, was in the very highest flood ever known. In 1878 a portion of the Zaloon Embankment, about two miles below this breach, which had been repaired, was carried away by the river during flood, and a considerable body of water passed over the edge and through the crops. No damage whatever resulted, though petitions and complaints came in daily while the flood was up. Just now over a mile of new retired line is being thrown up here at a cost of nearly 24,000 Rs. Its distance from the edge is not less than 700 feet. If, instead of this being done, the gap were left open, and the flood passing through were guided to a large interior drainage creek, a portion of land not more than 5,000 acres might, if the flood rose high, be thrown out of cultivation temporarily, possibly for 3 years. But a new high permanent bank would be formed, and the engineering difficulty, the seriousness of which can hardly be appreciated but by Engineers, would be overcome. The writer suggests the experiment being made, but cannot take the responsibility of actually recommending it; as it is likely to raise strenuous opposition from the revenue authorities. It is, however, by far the safest and the cheapest course to be pursued, as it allows nature to carry out unmolested the processes by which the present delta has been formed. The need of recurring to this means has not yet arrived, as the attack of the river on the embankment line has hitherto been small, and while it continues on the present scale can be met by partial retirements of the work.

The Tharrawaddy Embankment.

235. The survey and levels for the Tharrawaddy Embankment have been taken on the line marked in Plates IX to XVIII. It is everywhere on the eastern permanent bank and generally at a great distance from the eroding action of the river channel. The only place to the north of Thambyading where it approaches the main channel is at Yaygheen where little variation seems ever to have been experienced in the channel. Even here it is now over $\frac{1}{4}$ of a mile away from the main stream; a large sand bank intervening. To the south of the Thambyading bend it comes more within the scope of the river action, which occasionally there reaches the eastern permanent bank. There is a decided set on this bank above Sarawa, in one of the curves of the Thambyading bend. When the cut-off takes place there will be a change in this action. In the meantime should the work be undertaken this part ought to be left open to the free play of the flood water. From Sarawa to a considerable distance south of Zaloon the main channel does not approach the eastern bank; but at Ahpyouk and at Sagagyee it is eroding this side of the river slightly. To the south of this last place it hardly touches the permanent bank again, the exception being at Yandoon where a strong local action has been felt for some years. It appears probable that so far as the main river is concerned the proposed embankment can now be carried with perfect safety on the high edge of the left permanent bank from Talokmoh to the south of the Thambyading bend; and that when the cut-off takes place here the safety will be increased. It may in some respects be expedient, however, to wait for that event before putting the work in hand. But no alternative whatever is open in the site of the work. Any variation of this beyond narrow limits must on the one side place it in the low inner ground, or on the other bring it too near the edge of the bank. Its average distance from the western embankment is above four miles.

Its alignment.

236. In connection with this it is necessary to note an extract from Colonel Stoddard's Report (1869). Colonel Fraser had in a map in 1868 shown the alignment of the work as now proposed, on the edge of the permanent bank, which is everywhere far from the main channel. He had chosen this line after consultation with the local officers who were familiar with the country. Colonel Stoddard writing of Colonel Fraser's plans says :—"My proposals will be found in no particular opposed to those views, excepting on one point, and that the *distance* of the embankment (which it is proposed to throw up along the whole front of the river on the eastern side) from the edge of the river. In the large map submitted to the Government of India, with Colonel Fraser's letter No. 304-4 C-a., of the 23rd June 1868, I observe that it is proposed to place this embankment fully a mile from the river. From my experience in the Godavery where the embankments on both sides are not more on the average than 200 or 300 feet from the river, I am of opinion that no danger is to be apprehended on the Irrawaddy by placing them at the same distance. There are points on the river, doubtless where it would be prudent to place the embankment further back from the river owing to "sets" of the current and consequent erosion of the banks, but for this there is a remedy, as I hope to show before I close this report. I consider that the Irrawaddy is a much easier river to deal with in this respect than the Godavery—1st. It rises very much more gently. I have known the Godavery to rise as many feet, as the Irrawaddy does inches, in 24 hours; 2nd. The latter river is not dammed across by a weir as the Godavery is which tends to rise the level of the flood higher.

Colonel Stoddard's proposals.

"Moreover, by throwing the embankment so far back as one mile, or even ¼ of a mile from the river, much valuable land, indeed it may be said truly the most valuable portion of the land (from the fact of the best and richest particles of silt having been deposited on it) will be left outside and at the mercy of the floods. This valuable strip of land will eventually, when the population is sufficiently increased and irrigation becomes a necessity (which it will surely do throughout the delta, perhaps not many years hence) be rerequired for cultivation, and, secondly, owing to the rapid slope of the ground from the Irrawaddy towards the Hline, the embankment will be placed on lower ground; it must therefore be raised higher than if it had been constructed nearer the river. This will add to the expense, and will besides, increase the danger of the embankment being breached, so that there is no advantage gained by constructing it so far from the river, unless it be that the greater width given to the river in time of high flood will keep down the level of the water and so render a lower embankment sufficient; but this is a very doubtful advantage as against the saving in the first construction of the embankment must be set the loss of revenue from such a considerable extent of the best land being left exposed to the floods."

237. Colonel Stoddard's remarks are valuable in many respects, but he has here not distinguished between the bank of the main channel and the permanent bank of the river, which is the true boundary of the flood channel. It is only when the ground has been extensively traversed, and numerous levels taken, that the distinction becomes demonstrated. This is now done by the several cross sections of the channel shown on the plans. It now seems almost unnecessary to quote the error, but as it is one new comers may again fall into; or as the reasons for taking the new line so far from the edge of the main channel may not be immediately obvious, it appears better to answer such objections by referring to those cross sections. The high continuous bank is thus seen to be always the permanent bank. All others are broken and irregular, and intersected by minor channels. And there is a great advantage which cannot be overrated in leaving, where possible, a large scope for vagaries of the main channel, and for the storing up of the flood waters. The importance of giving abundant room in the flood channel has been recognised on the works on the Po where the greatest possible allowance

Present alignment the best possible as proved by the cross sections.

is made for the flood waters to accumulate. The necessity for this becomes less on approaching the head of the bed of deposit, where free escape is offered to the waters through the increasing number of branches of the river, and in bringing the embankment closer to the main channel to the south of Donabyoo and then restricting the section of the river, the course indicated by nature as the best is followed.

SECTION IX.

The vertical variations of the Irrawaddy and the Embankment works.

The dry weather channel:

238. The lateral variations of the dry weather channel are of slight importance of themselves, and only call for notice in so far as they coincide with those of the flood channel, and indicate the presence of bars. In general the dry weather channel oscillates from side to side of the larger channel, and gives longer length of course to the river at low water than at high, when the current strikes in direct lines from bend to bend, or shapes the outline of the river. At extreme low water the river surface is no longer parallel to that of flood. The bed is a succession of pools and bars, the latter being always found where the main channel flood current strikes across from one bank to another with an abrupt change of direction. These bars hold up the water in the reaches of the river immediately above them, and thus form deep pools of easily navigable water, which has generally only a slow flow; but the bars themselves cause prominent shallows over which the water flows, often with great violence, from the upper to the lower pool. They sometimes present serious obstacles to navigation in rivers, and engineers have occasionally advocated their removal by guiding and training works diverting the current on them. So long as this is done with moderation, and limited to deepening a narrow channel across them sufficient to pass vessels, good results are obtained often at small cost; but it has been pointed out that these bars are often indispensable conditions to the navigability of a river, by breaking up the total fall of its surface into a number of partial falls, and restraining the too rapid flow of the water. Any regulating works on the dry weather channel, which, when of a temporary nature, are generally of small cost, should thus be confined to the minimum requirements demanded by navigation, and should be exclusively confined to enabling vessels to pass these bars. Fortunately there is at present no urgent call for such works on the Irrawaddy. Numerous bars exist at all parts of its course; but it is obvious that it would be inexpedient to attempt any improvements on bars in one part without carrying them through to all. The largest native boats and the Irrawaddy Flotilla Steamers have been especially built to overcome any difficulties presented by these bars, which from Mandalay southwards, very rarely have less than 5 feet of water upon them; and though some days delay is occasionally caused by a particularly difficult one, no permanent obstruction to navigation has yet been experienced.

Pools and bars.

No improvement urgent for present navigation purposes.

The Kyangheen Bar.

239. The worst bar at present found in the length of river under consideration from Saiktha to Yandoon, is between the two curves of the S bend at Kyangheen. This is somewhat variable in position, and has grown more formidable as the curves have taken a sharper curvature. Lines of soundings were taken from Saiktha to Yandoon in 1877, the position of each sounding being fixed by angles taken on to the survey posts and flags surveyed along the rivers edge. It was intended as far as possible to follow the line of deepest water, the *thalweg* of the river, but the thread of the current does not always follow the *thalweg*, although erroneous notions often assume it to do so, and as the thread of the current was generally followed, the soundings do not give an exact profile of the pools and bars of the bottom of the river. But where any important point such as the Kyangheen bar was met with, two or three, or more, sets of soundings were taken, in this case by different observers. All soundings have

been reduced to the level of the surface at the river gauges noted on the day of mimimum discharge in 1877, when the smallest quantity of water ever passed down was recorded. A profile following the principal line of soundings is given in Plates IX to XVII; where also the more numerous depths are recorded on the plan of the channel. From these it will be seen that the Kyangheen bar is not exactly at the neutral point, where the current is pretty straight between the reverse curves, but occupies about half a square mile in extent of the channel at the lower end of the first curve. And even in this part a few deep soundings of nearly 20 feet are met with; but it is believed they are not continuous, and the channel is not available for the broad steamer towage in the early part of the dry season, though it improves towards March April and May.

Progressive elevation of Kyangheen Bar with increased sharpness of the curves.

240. The most remarkable feature about this bar is the progressive elevation it has undergone as the curves have acquired greater intensity. This is shown by the level of the water surface recorded on the Saiktha gauge. Unfortunately this has not been kept up continuously; but was recorded during the dry seasons of 1873, 1876, and 1877; and it is thus available for comparison with the other gauges. In the first year 172 million tons were discharged on the 1st April; the gauge then reading 0·73 feet, or 38·59 feet above mean sea level. When, on the 11th March 1876, 173 million tons were discharged, the gauge read 2·95 feet, or 40·81 feet above M. S. L. On the 27th March 1877 the corresponding gauge figures for the same discharge were 3·25 feet or 41·11 above M. S. L., a rise of surface of $2\frac{1}{2}$ feet in 6 years. The flood discharge at Saiktha does not appear to have varied in the same degree. It is not possible to follow the variations of the different gauges down stream from Saiktha with any accuracy as the volume of water changes much on its downward course according to the shape of the wave. On the next two gauges, at Myanoung $15\frac{1}{2}$ miles lower down, and at Shwegyeen 35 miles lower, the water was relatively lower about the above dates in 1877 than in 1873; while at the succeeding stations it appears somewhat higher. As all the low water records are thus liable to vary from year to year at each gauge it is difficult to use them, for a limited period of observation, as true indicators of any general change in the height of the bed of a river.

Data insufficient to judge of changes in the elevation of river bed.

241. They are, nevertheless, as Lombardini pointed out, the best datum points for reference if only the observations are taken over a sufficiently long period; and if, from time to time, accurate gaugings are made of the discharge. The Irrawaddy records, extending over only 9 years for the longest period at any gauge and over shorter times for several gauges, are too limited in number to draw any conclusions from as to changes in the elevation of the river bed, especially as the dry weather discharges are not gauged. It can only be from a comparison of the whole of the records *in decades*, after a long time shall have elapsed, that any inferences of value can be attainable. It is thus impossible now to answer or to elucidate from the data at disposal any questions such as have been put regarding the elevation of the bed of the river in the region from Saiktha southwards where the embankment works are in course of construction. The nature and importance of this branch of the subject may be gathered from the following extracts from memoirs and reports on the Irrawaddy works. Mr. W. B. Macrone, (1) in commenting on Colonel Fraser's original proposal for a double embankment on this portion of the channel said under date 22nd December 1867.

Importance of the subject, opinions quoted.

"On engineering grounds it seems to me that grave questions arise for consideration, regarding the complete embanking of the Irrawaddy. The few authorities on river embankment I have consulted appear unanimous in stating that the effect of embanking a silt-laden river is the gradual rising of its bed, necessitating,

(1.)—Reclamation of waste land in British Burma. Papers on—1868.

sooner or later, an increase to the height of the embankments. I believe that this is the experience from the embanked rivers in Italy, in America and in India."

Further opinions quoted.

242. Colonel David Brown, writing on the same proposal, says :—"I would not attempt to shut up any of the large outlets of the Irrawaddy. By confining it to one channel the velocity of the river will be increased; greater erosion of the banks than there now is will take place, and the bed of the river will rise more rapidly than it now does." Mr. Bennett in the same series of papers says :—"I believe Mr. Macrone has ably and concisely stated the opinion held by many engineers of the present time as to rivers flowing through alluvial formations and carrying on large quantities of silt in their waters. It may however be noticed that these embankments are intended to be far retired from the banks. This would be one point mitigating the evil result mentioned by Mr. Macrone as likely to occur, another would be, that, after all, the length proposed to be embanked is very short and when it is seen that from the Panlang creek the river has its free course downwards without hinderance, the portion so enclosed by bunds would only run the faster and probably increase the river somewhat in width and consequently carry its silt further down. So that really the raising of the bed to injurious results, would if at all, be the work of ages." The writer of the present Report in his paper of 1868, commenting on this point observed :—"I do not see any reason to apprehend a raising of the bed through embanking the east side. The bed of this river at Prome, where the amount of water carried is nearly the same as at Myanoung, is not raised by the flood water being naturally retained. Nor is it higher up. The deposition of silt on the bed is more likely to be diminished than increased by any acceleration of the velocity of the stream. A raising of the bed might be expected to take place if it could be shown that the velocity of the stream between Myanoung and Nyoung-doon were generally less than in the upper portion of its course; or if any retardation occurred between those places. But in either of these cases the raising of the bed would take place at all times, and independently of embankments, though it might be accelerated by them." Colonel Fraser in reviewing these opinions under date 16th June 1868, favours the idea of the river raising its bed. "A river is always, as it seems to me, raising its bed and embanking itself, we desire only to embank by art so as to utilize more quickly the country which would eventually be naturally utilized. I have no doubt that the sea once washed the spurs of the Aracan Hills up to Akouktoung, and the country has been raised by the constant deposits of these rivers, which is gradually going on 300 miles to the southward of that. A river channel naturally rises bodily in course of time from the constant deposit of silt."

The country has been raised by the river which has also raised its bed.

Investigations ordered on this point

243. His Excellency the Secretary of State for India called attention to the same question in letter No. 107, dated 15th December 1870, "I have had before me in Council your Excellency's Despatch No. 134 of 26th August last, and the papers therewith enclosed relative to investigations undertaken under your orders by Lieutenant-Colonel Stoddard in connection with a project for embanking the river Irrawaddy."

"In speaking of the results of these investigations you observe that "so far as can be judged at present there will be no objection whatever to having embankments on both sides of the river, so far as their effect in raising the flood surface is concerned" you consider however that the conclusions arrived at by Colonel Stoddard required to be confirmed by further enquiries which have accordingly been ordered, and which I would suggest should include among others one point which seems to have scarcely received as yet sufficient attention. I allude to the effect which the embankment of sides of the river might have in raising the level of its bed.

"According to Colonel Stoddard it is allowed on all hands that the Irrawaddy has every tendency to deposit sand and silt on its left bank, in so much that the consequence of making any artificial cuts from that river to the Hline would be that the cuts would be choked up with sand in perhaps the very first fresh. If this view be correct the consequence of attempting to confine the river between the existing western embankment and a new one to be formed on the opposite side might be a corresponding deposit on the bed of the river causing the surface level to rise proportionately and necessitating periodical additions to the height of the embankment."

The tendency of a river to raise its bed is only found on the bed of deposit.

244. This question and the others allied to it have received the fullest possible consideration in the course of the researches made. We have, as already stated, no data on the Irrawaddy itself which can lead to precise and definite conclusions; but we have the testimony, clear and absolute, of the eminent engineers of the Po, the Rhine and the Mississippi, which have been quoted at length proving that on the *trunks* of these rivers no such raising of the bed, as is feared, has occurred. And again, reverting to the division of M. Surell of rivers into reception basins, trunks and beds of deposit it is found that there is room for all the contradictory anticipations and conclusions to be true, and upon the same river. In certain conditions the river channel and the entire surrounding country are being raised. It is more than probable, it is certain, that the process described by Colonel Fraser for the Irrawaddy is correct; and that, while the bed of deposit of the river continued to commence at Saiktha, the whole lower region was being raised by the annual increment of alluvion. And a definite answer can now be given in this respect to questions regarding any part of a river, when we know for certain whether that part is included within the basin of reception, the trunk, or the bed of deposit. In the former case the channel and the country are being lowered by excavation. In the second case the process of deposition is nearly compensated for by continuous erosion. In the bed of deposit land must be made both horizontally and vertically. The works on the Po, on the Garonne, on the Rhine, and on the Mississippi where the testimony quoted relates to them, are wholly on the trunk above the bed of deposit; and thus the results obtained upon them can only be expected to follow from works executed upon the trunks of rivers. In deltas, when these are coincident with the beds of deposit, different results may accrue, dependent on the particular conditions of the locality.

The Irrawaddy channel from Saiktha to Yandoon is at present within the bed of deposit.

245. The question is thus reduced to an enquiry:—is the portion of the Irrawaddy channel between Saiktha and Yandoon, where the proposed double embankments are to be carried, a part of the trunk of the river, or is it within the bed of deposit? If it lies in the former, or if its condition and régime will be so altered by the works as to convert it into the trunk of the river, the double embankments can be executed without any fear of raising the bed above its present height; and with some probability of lowering it. As a matter of fact this portion of the Irrawaddy channel at present is, and must remain, so long as the flood waters are allowed free exit by other courses to the sea, within the region where silt is in course of deposit. The rate of this precipitation may be small, and can only take place on the surrounding country when the water tops the banks, or breaches through them; but when once the channel assumes the condition of giving off a portion of its burden without receiving any return it becomes a depositing agent; and, as the waters still continue to rise above the banks at very high flood, the bed of the river must follow *pari passu* in any increase of elevation given to the surrounding country. In all other respects the channel from Saiktha to Yandoon fulfils the conditions of the true trunk of the river such as we find it in the rock-bound region above the delta. It has a fall of surface in excess of its requirements for carrying away

the water and more than sufficient to transport all the silt and alluvion brought down to it from its upper parts. And by entirely shutting in to it the spill water now allowed to run over and through its banks into the Hline any possibility of further deposition of silt on the country will cease; the current will continue sufficiently powerful to keep the present channel clear, or even to increase it sufficiently to carry any extra discharge due to embanking; and the head of the delta, and of the bed of deposit will be finally transferred to the neighbourhood of the Pantanaw river, to the south of the region considered. This portion of the trunk of the Irrawaddy will thus be in all respects analogous to those of the rivers whose examples can be confidently relied upon as giving assurance of perfect safety against all raising of the bed through carrying out the works.

But double embankments will bring it into the condition of the true trunk of the river.

246. The numerous bars existing in the river channel are found, as before described, at points where the current changes its direction from bank to bank. The curves though they sometimes assume nearly a semi-circular form are almost always parabolic, even in the slightest curvature. Taking a list of the bars from the large plans and sections (Plates IX. to XVIII.) the most prominent of them measured along the channel from Saiktha southwards were about the following miles in 1877:—$5\frac{1}{2}$; 8; $12\frac{1}{2}$; 25; $27\frac{1}{2}$; 36; $43\frac{1}{2}$; $45\frac{3}{4}$; 51; 62; 65; $68\frac{3}{4}$; $72\frac{3}{4}$; $75\frac{3}{4}$; 87; 90; 103; 106; $110\frac{3}{4}$; and 117. The majority lie at the lower end of the curves just where the excavating action ceases to be most powerful. The deep parts of the river are found often close in shore on the concave side of the bends, or in the long straight reaches where the current has unimpeded play. The form of the river bed not only changes with local changes in the bars due to variations in curvature such as exist at Kyangheen; but it is alleged that in some parts of this and other such rivers there are continual changes in the channel with the rise and fall of the floods which scoop out and reform the pools and bars from season to season. It is extremely probable that this process goes on in the softer alluvial lining of the channel. The cross section of the channel at Zaloon varied very much in the flood seasons of 1872-73 as the discharges were being measured; and it had to be continually re-taken to obtain anything like the approximate discharge. But the Saiktha cross section was much less variable; and though it was often taken in the course of the observations, it did not vary much from low water to flood in the one year; though it gradually varies from year to year. Data are wanting to determine the extent to which the scooping out and reformation of the channel reach throughout this part of the river; nor is it for present purposes of great importance to have the information.

Position of the bars and deepest parts of the channel.

247. Possibly the only importance of it is in determining the shape of the river surface, which formed one of the principal objects of enquiry. Sufficient has been said to show that so far from the low-water surface forming a continuous plane of even slopes throughout; it is a series of planes of varying slopes alternating from the utmost attenuation in the deep pools to sharp steep slopes on the lower sides of the bars. It is thus difficult to assign any general slope for the low water surface of the river; although the total fall from Saiktha to Yandoon in March 1877 was 40 feet in 144 miles of main channel. The lengthening out of this by oscillations of the current may have brought its total length up to 160 miles, which would give a surface fall of about 3 inches per mile on the average. The high flood fall of August 1875 was 58·86 feet in the 144 miles; an average of 0·409 feet, or nearly 5 inches per mile. The average slope in 1877 would be slightly greater than this and at all other stages of the river the surface fall would, on the average, for this part of the channel vary from 3 inches to 5 inches per mile.

The low-water slope of the river. Average slope.

Average high flood slope.

248. The real slope however varies sometimes widely from this average. Taking the 1875 flood as the datum line, and dividing the channel into lengths to correspond with the different stations, we have the following falls from Saiktha southwards.

Actual variable slopes.

Table 23.

Stations.	Mile from Saiktha.	Interval Distance.	Height above mean sea level in feet.	Difference.	High Flood fall per mile in feet.
Saiktha	0		77·86		
		15½		6·95	0·449
Myanoung	15½		70·91		
		19½		9·57	0·491
Shwaygheen	35		61·34		
		16		7·57	0·473
Nyoungyo	51		53·77		
		33		10·29	0·312
Henzada	84		43·48		
		17		7·49	0·441
Zaloon	101		35·99		
		29		11·52	0·397
Donabyoo	130		24·47		
		14		5·47	0·391
Setkaw or Yandoon	144		19·00		

There is here a very variable distribution of the flood fall in the different lengths of the channel. The greatest slope is in the nearly straight reach from Myanoung to Shwegyeen. At this latter place the current has acquired a much greater velocity than in most parts of the channel, and only the more powerful steamers with laden flats can stem it. The acquired impetus is doubtless used up in shaping the succeeding Monyo curves. It is curious, however, to find that the channel interval from Nyoungyo to Henzada, which contains the greater curves of the river, where the erosive action upon the banks is most intense, should have the least slope; viz. 0·312 feet per mile. But on a great length of these immense detours of channel there is little eroding action; and notwithstanding the changes of level induced in the water surface above and below the bend by its gradual formation, the sinuous lengthening out of the channel must have greatly reduced the slope per mile of channel in these portions. Bearing in mind that the mean surface slope from Saiktha to Setkaw is 0·409 feet per mile, there is evidently a loss of fall in the length referred to, with corresponding gains in the portions just above and just below. Taking these four lengths together we have a fall of 34·92 feet in 85½ miles from Myanoung to Zaloon, which gives an average of 0·408 feet per mile; almost exactly that of the whole length considered. It is probable then that the disturbance of level of flood surface due to the Thambyading bend does not extend much beyond those limits; and, when the river resumes its old course across the neck of this bend it will be of the utmost importance to have some assurance that the re-arrangement of surface levels will not extend in the lower part much beyond Zaloon. Unfortunately this cannot be relied on implicitly; and the expected rise of nearly 3 feet in the flood level above Henzada will hardly attenuate itself to nothing in 20 miles of river channel to Zaloon. Precautionary measures will have to be undertaken lower down; though of a less expensive kind than near Henzada.

249. The normal surface, if that expression can be used of a continually varying regime, in the channel from Saiktha to Setkaw, must according to the general rules of river slope, have a continually diminishing slope in its downward course. The 0·391 feet from Setkaw to Donabyoo, and the 0·397 feet from Donabyoo to Zaloon represent the probable shares of the average slope which would gradually increase for each length of channel up stream, within

Gradual diminution of slope in river surface on approaching the sea.

the limits of the present delta. The height of the 1875 flood at Prome was 93·07 feet above mean sea level. The distance of the bench mark from Saiktha gauge is about 36½ miles along the river bank. Measured along the thread of the current the distance is very little more; at the outside it is 38 miles in flood. The difference from Prome (93·07 feet) to Saiktha (77·86 feet) in 1875 high flood is 15·11 feet or 0·397 feet per mile; a slope very near in amount to that from Saiktha to Yandoon. The high flood of 1877 stood at 116·5 feet above mean sea level at Allanmyo, 42 miles above Prome; and as this flood was recorded to be 2′ 2″ above that of 1875 at Thayetmyo opposite, the 1875 flood surface had a fall from Allanmyo to Prome of 21·26 feet in 42 miles; or just over 6 inches per mile.

Difficulties found in determining the true slope of a river.

250. There are here some anomalies in the surface fall of the lower part of the trunk of the Irrawaddy which are somewhat difficult to account for without going into a closer examination than is suited to this report. The difficulties found here, however, are comparatively simple when contrasted with those met with in endeavouring to determine the true slope of the river in all conditions, even when the circumstances are most favorable. This question of surface slope is one of the utmost importance both to practical Engineers, and to the analyist of mechanical science. It forms, as it were, the pivot upon which all the formulæ for the flow of water, and all the theories upon it depend; and although theory can accommodate itself with approximate solutions, no formula for the velocity or discharge of rivers can be of any service unless this, the principal factor of the formula, can be accurately determined, on any given section of the river or stream concerned.

Investigations for surface slope on the Irrawaddy.

251. No point of the enquiry has formed the object of more solicitude in the Irrawaddy investigations than this—the accurate determination of the surface slope. It is impossible to do justice to the results obtained, in a report of a general character. The conclusions drawn should be supported by the whole mass of detailed evidence in order that the value of each disturbing element may be appreciated. The present report, intended to be general, is already overburdened with details and tables, but, if the subject is touched upon at all, a portion of the detail must be given. The only alternative to postponing the discussion entirely until all the figures can be presented, is then to give a general description of the aims of the research, of the methods pursued, of the results attained, and a specimen of the detailed measurements. An extract from a previous paper will assist in defining the aims of the investigation. In his Memoir "On a new formula for the flow of water in open channels" the writer said in 1873:—

Result of former researches.

"The surface slope of the river is one of the most difficult points the practical hydraulic engineer has to deal with. The highest flood level of different points of the river have been accurately connected by levelling for over 110 miles, and the average slope found to be about six inches per mile. At Myanoung, 14 miles south of Saiktha, and about 200 miles from the sea, the highest flood mark is 76 feet above mean sea level, by the Grand Trignometrical Survey level. (1). The range of the river from highest flood to low water is about 40 feet at Myanoung, thus reducing the fall to the sea at low water to about one half what it has at high. The range at different points varies. At Saiktha it is over 42 feet. At Henzada 74 miles south of Myanoung 36 feet, and at Zaloon 34·5 feet. This surface slope would then be altered from high to low water by this cause alone, but there are other causes of variation. Thus there are several basins (*bassi fondi*) in this part of the river with ridges forming lips at their lower side, where steamers drawing only 4 feet of water are frequently stranded. These ridges hold up the water for many miles when the river is low, and while the slope above them is there reduced, it is much steeper immediately below them. In

(1.)—This differs from the Railway levels by 4½ feet at Myanoung.

addition, the river when in full flood takes a much shorter course than when in the dry weather channel, so that if even the difference of level between any two points of the surface were the same in the different stages, the lengthening out of the course would considerably alter the surface declination. Now the declination can only be approximated to by a series of averages. A short line of levelling along the bank, however accurately taken, will not give the fall on the thread of the current. This may be passing from one side to the other, or if it is parallel to the bank the local peculiarities of the channel may back up the water in some places or give it a more than average fall in others. Thus the low water surface of the Irrawaddy has been found to vary from 2 to 4 inches per mile, while in some parts it is more. This difficulty would subsist if the surface were always a plane, varying regularly; but, in truth, it varies with every undulation of flood, and with the rise or fall of the surface the declination may vary several inches. It is almost impossible to obtain an accurate record of each variation for the different discharges, and thus a serious disturbing element is introduced. We know, however, that if the surface were a plane the slope would vary with some regularity within certain limits. Thus at Saiktha at the very highest flood (gauge reading 40) the general slope on 10 miles was found to be 6·68 inches per mile. At a gauge reading of 36, it was about 6 inches; and at the low water it is between 3 or 4 inches. By taking discharges of the river when it is above the low water channel, say between 14 and 36 feet on the gauge, we can have a set of data to test the formula by. The slope which is not accurately known for the various stages is taken to vary regularly from 6 to 5 inches per mile between 36 and 12 feet."

Measurement made in 1872-73 at Saiktha.

252. This expresses the result of a series of desultory measurements by levelling of the surface slope of the river at Saiktha in and previous to 1873. It was not found possible to fix any definite slope for, say each gauge reading, at four feet apart, from the measurement made. Bench marks had been fixed half a mile above, and the same distance below the Saiktha gauge and the difference of level noted at different times, while isolated levels were carried occasionally along the shore at other parts of the river. Most discordant results were obtained. In some parts at low water, the slope along the edge was almost imperceptible. In others it was excessive. The strength and direction of the wind influenced the results according as it struck the surface at the part measured. Undulations of the river surface appeared sometimes to pass and vary the slope. A different slope was found when the river was rising from that when the water was falling. It was necessary to strike an average from the levels made, this average as above given being from 5 to 6 inches per mile near Saiktha, on gauge readings between 12 and 36 feet. As will be seen subsequent experiments prove this assumed slope to be in excess.

Renewed experiments at Saiktha in 1876-77.

253. As no satisfaction could be obtained from desultory observations, and recorded experiments on other rivers gave similar discordances, it was determined to institute a systematic taking of the surface slope daily for a lengthened period. It was of the utmost importance that this should be done at the Saiktha gauge, as the most accurate and extensive observations had been made there, but as Saiktha is over 12 miles away from the residence of the supervising officer, who lives at Myanoung, a corresponding set of observations was simultaneously to be made at the latter place. In June 1876 two sets of gauges were fixed for measuring the surface slope; one at each of the above stations. They were as far as possible similar. The sites and positions of the gauges are shown in Plate IX. That at Saiktha was determined from the measuring cross section, and gauges were fixed one mile above and one mile below the western end of this; where the permanent river gauge stands. On the eastern side one gauge was fixed at the end of the measuring

Further experiments at Myanoung.

The Saiktha sets of gauges for surface slope.

section, and another at one mile above it. The former was dry in the low water season; but separate posts were carried out to the waters edge as it retreated. In 1877 a third gauge was fixed at two miles above the cross section on the east side thus giving a complete set of six gauges, three on each side with intervals of one mile between each pair. The distances were measured along the river bank by chaining, but, when triangulated, were found to be on the east side upper gauge to middle 5,250 feet, middle to lower 5,310 feet. On the east side they were 4,950 feet and 5,250 feet respectively. These figures have been taken in reducing the slopes between the extreme gauges. The results are given in inches per mile. The gauges were all wood. Two kinds of gauge have been used; the one of strong teak timber sloping in a straight line from the crest of the bank to the waters edge and bolted to vertical posts; the other consisting of a series of vertical posts fixed below each other in a straight line from top to bottom of bank. When this was nearly vertical the sloping gauge acted perfectly; but it failed where there was very much inclination, as when the water fell and left it, the power of the sun tended to warp it and alter the readings. These sloping gauges were at first used at all the places in 1876; but the Saiktha ones were found to have changed in parts from one to two inches, so that the whole of the records for that year were rejected, and in 1877 strong ironwood posts were let vertically into the bank. Masonry bench marks were built on the bank near each gauge, and accurately connected together. A line of levels was then run down to each gauge, and each foot carefully marked on the posts. The feet were divided into inches, marked on the posts, and smaller sub-divisions were noted by means of rules. The gauges were in more or less sheltered positions, but occasionally the water undulated on the face of the gauge. In this case a mean was observed of the range of this undulation and this was recorded. No instrument such as an open glass tube was used for moderating the undulation, which only rarely required to be allowed for. From time to time the gauges were tested by the levelling instrument; and every precaution was taken to ensure the utmost accuracy. The Saiktha records were only read on the vertical posts in 1877-78.

The Myanoung set of gauges.

254. At Myanoung a set of five sloping gauges was fixed in a similar manner; three on the west bank; and two on the east. The former were arranged one on each side of the permanent gauge; the latter had to be placed as shown on the plan, as the bank being broken and faced with shoals above and below permitted no other arrangement. The distance apart of the upper and middle gauge was 5,230 feet; and of the middle and lower 5,270 feet. The recording of this series of gauges was continually under supervision; and they are useful in checking those at Saiktha, which could only occasionally be checked. The sloping gauges continued to be used here throughout the whole period from 1876 to 1878; and at the end of that time were found to almost perfectly accurate.

Detailed records of both gauges for the years 1877-78.

255. The detailed record for the year from March 1877 to February 1878 inclusive is given for the Saiktha gauge in appendix VI. An abstract of this is given in Table 24. This takes out for each foot of the gauge the averages of each consecutive set of readings in the rising or falling state of the river separately. It also gives means of these averages throughout the year. A similar abstract is prepared from the Myanoung set of gauges; the details of the observations being given in Appendix VII. There is a close similarity between the conditions attending the two sets of gauges, as will be observed in Plate IX. In both cases what may be called the primary series of gauges are fixed on the right bank where it is parallel to the thread of the current, which is close into the right bank at Saiktha; but follows the more central part of the channel at Myanoung. The secondary gauges on the left bank are in both cases somewhat disadvantageously situated above sandbanks which interfere with the regular flow of the water. At Saiktha the upper two of these are better than the others, and run more nearly with the current; but the large sandbank below interferes with the water slope

Situation of the gauges.

near the lower interval. At Myanoung the two left bank gauges have sandbanks above and low. The situation of the river channel with regard to the direction of the prevaling winds is also of the highest importance. At Saiktha the channel is very nearly due north and south. The south west monsoon is thus thrown off the water near the western gauges, by the trees and the high bank; but strikes the water surface in front of those of the left side. The north easterly winds affect the gauge readings in an opposite way. It will be seen that the effect of these winds is considerable on the gauge readings. At Myanoung the channel direction is more to the west of north, which tends to exaggerate here the disturbing effects of both winds.

Table 24.

Saiktha Gauges.

Gauge Reading.	Saiktha.		Talokmoh.	
	Rise.	Fall.	Rise.	Fall.
1 to 2	1·35	1·30	...	...
	1·31	1·41	...	...
Mean ...	1·33	1·36	...	...
2 to 3	1·44	1·37	·57	·62
	...	...	·69	·50
Mean ...	1·44	1·37	·63	·56
3 to 4	1·75	1·75	·50	·50
	·875	·875	·50	·60
	·97	·812	·65	3·74
	...	...	3·74	...
	...	....	4·02	...
Mean ...	1·198	1·146	1·88	1·61
4 to 5	1·00	1·105	·50	·50
	1·125	1·017	·50	·50
	·688	1·00	·65	3·28
	...	·88	·77	...
	...	1·21	4·06	...
Mean ...	0·938	1·04	1·28	1·42
5 to 6	1·045	1·125	·50	·50
	1·125	1·00	·50	·50
	1·125	1·05	·50	6·05
	1·165	1·31	·77	3·93
Mean ...	1·121	1·12	·57	2·74
6 to 7	1·625	1·19	2·75	2·42
	0·88	...	...	2·91
	1·30	...	...	...
Mean ...	1·27	1·19	2·75	2·66
7 to 8	1·25	1·48	...	4·19
Mean ...	1·25	1·48	...	4·19
8 to 9	2·00	1·70	1·03	2·06
Mean ...	2·00	1·70	1·03	2·06
9 to 10	2·00	2·125	1·03	1·28
	2·25	2·09	1·28	2·30
	...	...	1·28	...
Mean ...	2·12	2·11	1·15	1·79
10 to 11	2·06	2·60	1·06	1·06
	2·50	2·50	2·32	2·14
	...	...	...	2·27
	...	...	...	2·32
Mean ...	2·57	2·55	1·69	1·94
11 to 12	2·375	2·25	1·28	1·18
	2·63	2·44	...	2·18
Mean ...	2·51	2·35	1·28	1·68
12 to 13	2·375	2·25	1·10	1·18
	...	2·04	1·28	2·00
Mean ...	2·38	2·15	1·69	1·59
13 to 14	2·87	2·25	1·17	1·28
	...	2·44	...	2·12
Mean ...	2·87	2·35	1·17	1·70
14 to 15	2·375	3·00	1·17	1·28
	...	...	...	2·18
Mean ...	2·38	3·00	1·17	1·63

Gauge Reading.	Saiktha.		Talokmoh.	
	Rise.	Fall.	Rise.	Fall.
15 to 16	2·88	3·50	2·18	1·98
Mean ...	2·88	3·50	2·18	1·98
16 to 17	2·88	3.875	1·28	2·43
Mean ...	2·88	3·88	1·28	2·43
17 to 18	3·25	3·875	1·43	2·18
Mean ...	3·25	3·88	1·43	2·18
18 to 19	3·50	3·375	1·55	1·67
	3·50	3·69	1·92	2·18
Mean ...	3·50	3·53	1·93	1·92
19 to 20	3·125	3·25	1·94	2·69
	...	3·375	2·32	4·40
	...	3·56	2·63	
Mean ...	3·13	3·39	2·30	3·54
20 to 21	3·75	3·12	2·06	3·09
	3·68	3·625	...	2·44
Mean ...	3·71	3·37	2·06	2·76
21 to 22	4·00	3·38	2·06	3·09
Mean ...	4·00	3·38	2·06	3·09
22 to 23	4·00	2·28	2·14	3·34
Mean ...	4·00	2·28	2·14	3·34
23 to 24	4·37	4·50	2·18	2·26
	...	4·25	...	2·83
	...	4·625	...	
Mean ...	4·37	4·46	2·18	2·54
24 to 25	4·13	4·50	2·40	2·18
	4·25	4·50	2·95	2·31
	4·00	3·87	2·83	3·09
	4·50	4·125	4·12	
	4·875			
	3·625			
Mean ...	4·23	4·25	3·07	2·52
25 to 26	4·00	4·25	3·10	2·62
	4·62	4·75	3·57	2·83
	...	...	...	2·83
Mean ...	4·31	4·58	2·83	2·76
26 to 27	4·25	4·62	3·08	2·95
	4·91	5·00	3·10	2·80
	4·75	4·875	3·21	6·18
	4·22	...	2·83	
	...	...	3·09	
Mean ...	4·53	4·50	3·06	3·97
27 to 28	4·31	4·50	3·09	3·09
	5·00	5·00	3·34	2·95
	...	...	...	6·18
Mean ...	4·65	4·75	3·21	4·07
28 to 29	4·50	4·37	3·47	4·22
	5·00	6·50	2·57	
	5·00	5·12		
Mean ...	4·83	5·33	3·02	4·22

Gauge Reading.	Saiktha.		Talokmoh.	
	Rise.	Fall.	Rise.	Fall.
29 to 30	5·25	5·12	3·60	5·27
	...	...	3·09	6·18
Mean ...	5·25	5·12	3·33	5·72
30 to 31	5·00	4·88	3·60	
	5·00		3·28	
Mean ...	5·00	4·88	3·44	
31 to 32	4·81	5·50	3·60	6·43
			3·09	
Mean ...	4·81	5·50	3·34	6·43
32 to 33	5·00	5·62	3·60	5·66
	5·00		3·41	2·12
Mean ...	5·00	5·62	3·50	3·89
33 to 34	4·75	5·00	3·72	3·83
	4·75	5·25	3·20	
Mean ...	4·75	5·12	3·46	3·83
34 to 35	5·875	5·25	3·87	3·60
	5·125	4·75	3·34	3·59
	5·125			
Mean ...	5·37	5·00	3·60	3·59
35 to 36	5·25	5·35	3·98	3·92
	5·28	5·12	3·75	3·10
	5·15	...	4·10	
			3·60	
Mean ...	5·23	5·23	3·85	3·51
36 to 37	6·00	5·87	4·50	5·01
	5·33	5·25	2·90	4·63
		5·25	...	2·58
Mean ...	5·67	5·37	3·70	4·07
37 to 38	5·875	5·01	4·40	4·63
	6·00	5·75		
Mean ...	5·94	5·38	4·40	4·63
38 to 39	6·375	5·37	4·50	5·15
	6·00	...	5·21	5·40
				5·01
Mean ...	6·19	5·37	4·85	5·19
39 to 40	6·50	7·00	4·63	6·18
	6·25	7·00	...	6·18
Mean ...	6·38	7·00	4·63	6·18
40 to 41	7·00	6·94	4·79	6·70
			7·21	5·15
			6·18	
Mean ...	7·00	6·94	6·06	5·92
41 to 42	7·25	7·00	...	5·66
	7·25	6·875		
Mean ...	7·25	6·98	...	5·66

Table 25.

Myanoung Gauges.

Gauge Reading.	Myanoung.		Kyungalay.	
	Rise.	Fall.	Rise.	Fall.
1 to 0	1·759	1·759	·50	·50
	...	1·794	·50	·50
	...	...	·50	·45
	...	...	...	·50
Mean ...	1·76	1·775	·50	·40
0 to 1	1·727	1·759	·25	
	...	...	·75	
Mean ...	1·73	1·76	·50	
1 to 2	1·633	2·136	·33	·25
	2·136	2·010	·25	·25
	1·256	1·277	·25	·25
	...	3·392	·25	2·00
	..	...	2·00	
Mean ...	1·675	2·204	·616	·687
2 to 3	1·633	1·407	·50	·25
	1·507	1·633	·25	·25
	1·256	1·394	·25	·25
	3·392	3·392	2·00	2·00
Mean ...	1·947	1·956	·75	·687
3 to 4	1·256	1·630	6·16	·333
	1·507	1·517	1·875	2·00
	1·382	1·382	...	2.00
	3·643	3·504		
	...	3·895		
Mean ...	1·947	2·384	1·245	1·444
4 to 5	1·549	1·884	·50	·75
	1·712	1·987	·25	·375
	3·895	3·643	2·00	2·00
	...	3·769	...	2·125
Mean ...	2·385	2·821	·92	1·143
5 to 6	1·382	3·720	2·00	2·00
	3·643	3·895	...	2·00
Mean ...	2·512	3·807	2·00	2·00
6 to 7	...	3·610	·25	2·00
Mean ...	...	3·61	·25	2·00
7 to 8	...	3·42	...	2·00
Mean ...	...	3·42	...	2·00
8 to 9	1·382	3·955	·25	·25
	3·518	3·303	·25	·25
	...	...	·25	2·00
	...	...	2·00	2·00
Mean ...	2·45	3·63	·69	1·13
9 to 10	1·633	2·010	·25	·25
	1·759	1·759	·25	2·00
	1·884	3·549	2·00	2·00
	3·432	3·581		
Mean ...	2·18	2·724	1·125	1·41
10 to 11	1·834	3·675	·25	·25
	...	...	...	2·00
Mean ...	1·884	3·67	·25	25
11 to 12	2·136	·476	·25	...
	...	...	...	2·00
Mean...	2·14	3·48	·25	1·125
12 to 13	2·136	4·272	·25	2·25
Mean...	2·136	4·272	·25	2·25
13 to 14	2·136	2·136	·25	·25
	2·387	4·272	2·50	2·25
Mean...	2·261	3·204	1·375	1·25
14 to 15	...	2·136	...	·25
	...	5·261	...	2·25
Mean...	...	3·698	...	1·25
15 to 16	2·261	4·272	1·00	1·75
Mean...	2·261	4·272	1·00	1·75
16 to 17	...	...	...	2·25
Mean...	...	...	...	2·25
17 to 18	...	4·146	1·00	2·25
Mean...	...	4·146	1·00	2·25
18 to 19	...	4·272	1·00	2·50
	...	...	2·50	2·50
Mean...	...	4·272	1·75	2·50
19 to 20	4·272	4·146	1·00	2·00
	...	4·272	1·25	1·75
	...	...	...	2·50
Mean...	4·272	4·21	1·125	3·125
20 to 21	2·261	3·393	1·00	2·50
	4·020	3·643	2·25	
	2·890	4·272		
	...	4·020		
Mean...	3·057	3·932	1·625	2·50
21 to 22	4·272	...	2·50	2·50
Mean...	4·272	...	2·50	2·50
22 to 23	2·357	3·518	1·00	
Mean...	2·387	3·518	1·00	
23 to 24	...	...	...	2·50
Mean...	...	...	...	2·50
24 to 25	...	2·638	1·00	1·125
	...	3·392	1·25	1·25
	...	...	1·25	2·50
	...	...	·25	
Mean...	...	3·015	·937	1·625
25 to 26	2·763	2·952	1·50	2·00
	2·827	3·269	2·00	2·50
	3·269	4·774	3·00	
	...	3·769		
	...	3·895		
Mean...	2·912	3·73	2·166	2·25
26 to 27	3·015	3·267	1·50	2·00
	3·895	...	2·00	3·00
	...	...	...	2·50
Mean...	3·405	3·267	2·00	2·50
27 to 28	3·141	3·115	2·25	2·00
	3·267	3·769	1·75	1·50
	...	...	2·75	2·00
	...	...	2·50	2·501
	...	...	4·75	3·00
Mean...	3·204	3·442	2·80	2·20
28 to 29	3·141	3·015	2·00	2·00
	3·141	3·267	3·00	
	2·952	3·895	3·75	
	3·895			
	4·020			
Mean...	3·429	4·392	2·916	2·00
29 to 30	2·513	2·890	2·25	2·00
	3·392	3·140	3·75	2·50
	4·523	...	...	3·00
Mean...	3·476	3·020	3·00	2·50
30 to 31	3·392	...	2·50	3·00
	3·392	...	4·00	
Mean...	3·392	...	3·25	3·00
31 to 32	3·518	3·141	2·50	2·50
	3·769	...	4·50	
Mean...	3·643	3·14	3·50	2·50
32 to 33	3·392	3·141	2·50	3·00
	3·895	...	2·00	
	...	...	3·62	
Mean...	3·643	3·141	2·706	3·00
33 to 34	3·518	4·523	2·00	2·50
	3·706	...	3·75	1·75
Mean...	3·612	4·523	2·87	2·125
34 to 35	3·769	3·895	2·00	1·75
	3·267	...	4·05	
Mean...	3·518	3·895	3·025	1·75
35 to 36	4·104	4·523	2·00	·50
	3·737	4·272	4·416	1·75
Mean...	3·92	4·397	3·21	1·125
36 to 37	4·020	4·523	2·25	2·50
	4·114	4·209	2·00	2·25
	4·146	4·366	1·75	1·75
	3·958	4·272	2·25	
	...	4·460		
Mean...	4·059	4·366	2·06	2·16
37 to 38	4·963	4·635	2·25	1·50
	4·031	4·635	2·125	1·50
	...	...	...	1·75
Mean...	4·497	4·555	2·187	1·58
38 to 39	3·643	5·654	2·25	2·25
	5·151	...	2·00	
	...	...	2·25	
Mean...	4·397	5·654	2·16	2·25
39 to 40	4·272	4·146	2·25	
	5·433	4·586		
Mean...	4·852	4·366	2·25	
40 to 41	4·272	4·335	2·33	2·167
	...	4·146		
Mean...	4·272	4·24	2·33	2·167
41 to 42	4·209	...	2·625	
	4·146			
Mean...	4·176	...	2·625	

256. One of the most interesting questions regarding the form of a river surface is, whether on any given cross-section the upper edge is truly horizontal, or curved upwards or downwards. Observations on different rivers show that it is liable to vary; that sometimes the surface is convex, sometimes concave. It was not found practicable to measure the differences of surface levels at intervals across the Irrawaddy at any of the stations; but the two gauges fixed at the ends of the measuring station at Saiktha afford indications as to the variations from parallelism on that particular cross section. The gauge at the Saiktha end is fixed to read 40 feet at highest flood of 1875. This point was not accurately marked at the Talokmoh end of the section; but the reading of this gauge has since been adjusted to show 40 feet when the flood of 1875 reached that mark on the Saiktha gauge. On comparing the two records in the appendix it will be seen that they coincide satisfactorily at various points from above 40 feet down to 4 and 3 feet; but at the same time oscillations are noticeable at all heights, when sometimes the one gauge, sometimes the other reads the highest. Apparently the direction of the wind caused these variations, as, while on calm days at all seasons the coincidences of height occur at intervals from the 3 foot mark to the 40 foot mark, the record shows that during the south westerly monsoon from May to September the Talokmoh gauge reads slightly the highest, and the western or Saiktha gauge is higher when the northeast wind blows on it from September to February. No comparison can be made between the Myanoung and Kyungalay gauges as they were somewhat remote from each other.

Points of the enquiry to be determined. Is the cross section upper profile a straight horizontal line?

257 Great variations of surface slope following the seasons from low water to flood are noticeable at each separate set of gauges. Taking the Saiktha set first, we have a change of slope in the averages at each foot of gauge from about 1 inch per mile at the 4 to 5 feet interval to $7\frac{1}{4}$ inches with the rising flood from 41 to 42 feet. The graduated progress from the smaller to the larger slope is clearly marked. There is in the majority of averages a somewhat higher slope with the rising flood than with the falling. The same gradual rise of slope from little over $\frac{1}{2}$ inch per mile to about 6 inches on the eastern or Talokmoh side from low to high water is similarly observable; but the falling flood here appears to have the greater slope oftener than the rising. The changes of the mean slope at the same stations are remarkable. They are due to the changes in the amount of rise and fall of the river at the bar opposite Kyangheen and at Saiktha; and to the lengthening out as it were of the course taken by the water in the channel, as the surface falls from flood level. It will be seen that the averages of the Talokmoh side are on the whole lower than those at Saiktha. The difference arises from the different positions of the gauges relative to the current. The upper two gauges on the Talokmoh side appear to be more nearly parallel to the thread of the stream than the lower two; but all are further from it than the Saiktha gauges. None of them taken singly can be said to give the true fall of the river; though the Saiktha set must be nearer to it than the others.

Great variations of slope with different stages of the river at Saiktha.

258. The anomalies found in the separate observations as given in the appendix are even more instructive than the averages. The influence of the positions of the gauges relative both to the current and to the wind is most marked. There is a striking accordance between the observations while the wind blows regularly from one fixed quarter. It is owing to the prevalence of the northerly breezes in March that there is a slight excess in the slope with the lower gauge reading of that month over those of May at Saiktha. The transition from the surface slopes of the latter month to those of August is gradual and even, both at Saiktha and at Talokmoh, but during the very high floods some curious oscillations are recorded. Thus at Saiktha, the upper and lower intervals between the gauges have slopes of $6\frac{1}{4}$ inches and $6\frac{3}{4}$ respectively on 9th August with gauge at 39′ $10\frac{3}{4}$″. Next day at 40′ $8\frac{3}{4}$″ they are $7\frac{1}{4}$ and $6\frac{3}{4}$; and on the 12th at 6 and 8 inches respectively. At the very highest rise of the 19th the slopes are 4 inches in the upper interval, and $10\frac{1}{2}$ in the lower with gauge at

Anomalies in the observations at Saiktha.

41′ 10½″; the dislevelment being still further exaggerated on the 21st when the figures are 3 inches and 11 inches; the mean slope thus remaining nearly the same. Corresponding anomalies are observable during the same period on the Talokmoh side, with even more extreme results. On the 11th, the gauge reading 41′, the upper interval had a slope of 11½ inches, the lower of 2½ inches; the mean of that date, 7·21 inches, thus agreeing closely with the 7·25 of the western side. On the 18th the slopes were 11 inches and 1 inch. The upper interval here generally had a greater surface fall than the lower; but at all other seasons was much more nearly equal with it. It is not the purpose of the writer to generalize from these figures, the concordance of the anomalies of which verify their correctness; but he would call attention to the very striking light in which they place the difficulty of accurately determining the true slope of a river surface. If the gauges had been extended over a couple more miles of river length, possibly a mean of the whole would have given the true fall; but, as it is, any of the single slopes recorded would be entirely misleading; though the Saiktha averages are probably nearly the truth. The set of the current is the only explanation open to account for these high flood anomalies. Others arising from changes in wind direction are observable by comparing the slopes during the South-West monsoon season with those of the North East monsoon from September to March. In October the upper interval at Talokmoh had a slope of 6 inches with the gauge falling from 30 to 25 feet. The same excess slope again appears in January and February 1878. It is apparently due to the effect of the northerly breezes, which, coming generally with the falling river, give a larger surface slope at these gauges with falling flood than with rising.

Observations at Myanoung.

259. Similar accordances and discrepancies are found with the two sets of gauge records of the river at Myanoung, Table 25. The averages for each foot of the gauge readings range from 1·675 at 1 to 2 feet to about 5 inches at 39 feet gauge; thus showing a smaller range and a lower flood slope than at Saiktha. The difference is difficult to account for, unless it be that no bar of so pronounced a form as the Kyangheen one is to be found just below Myanoung. The extreme variation of the averages of continuous observation is from 1·256 inches in May to 5·433 inches in August, the thread of the current as before said lies at some distance from either bank; but nearer to the Myanoung side. The eastern gauges at Kyungalay read invariably a lower slope than the Myanoung ones. The north west monsoon exercises great influence on the lower interval on the Myanoung side, where in December, January and February it gives the very great fall of nearly 7 inches per mile. It must be mentioned however that the centre gauge is fixed close to a rocky shoal, which heaps up the water in the dry season near both the centre and the upper gauge. The extreme interest attaching to these records can only be appreciated by those who have been engaged with formulæ for the flow of water in rivers, and they would have been better reserved for discussions on that subject; but as they form part of the result of the operations connected with the general investigations into the shape of the river surface it has been found necessary to bring them forward with a few remarks of a general kind. Any more special notice can be given when the formulæ are again considered. In the meantime, all the elements necessary have been arranged so as to permit the principal results to be discussed.

The high flood surface with reference to the embankment works.

260. The figures given in Table 26, reproduced below, showing the heights of the various floods in the river channel are plotted in Plate VIII.

Table 26.

Stations.	1868 flood.	1871 flood.	1875 flood.	1877 flood.
Saiktha	...	...	77·86	79·74
Myanoung	68·47	70·15	70·91	71·87
Kanoung	66·19	67·23	68·07	...
Shwe-gyeen	59·55	60·50	61·34	62·09
Nyoungyo	52·17	53·77	53·77	54·10
Henzadah	41·19	42·48	43·48	43·78
Zaloon	...	35·47	35·99	36·41
Donabyoo	...	...	24·47	24·43
Setkaw	...	...	19·00	...

These levels are of the utmost importance in their relation to the past progress of the embankment works upon the Irrawaddy. Colonel Short's and Mr. Fennessy's datum points were taken from the records of some previous flood as pointed out by the villagers along the line of works; and the heights of the embankment were determined from these data. They must have been fairly correct, as the 1868 flood, though it rose from one to two feet higher in places than the points marked, on the whole was nearly parallel to the line of levels. The 1868 data above recorded are from levels connecting masonry pillars built by Mr. Bennett from accurate markings of that years floods taken at the time. This flood did not top the embankment works in any part, though in a few places from the 37th to the 44th miles of the Myanoung Embankment it nearly did so. It was found that the works as a whole were about 3 feet above the general level of that flood; especially where they had been designed to be 5 feet above the unknown former flood. The Flank Embankment was somewhat higher.

The 1868 flood.

261. The two breaches in the Henzada Embankment in 1868 were accidental and due entirely to the unfinished state in which the portion of the embankment behind Henzada was found by the flood. The position of these breaches and the extent of the works is shown in Fig. 1, Plate XX. Although extensive new works were designed between 1868 and 1871 only 4 additional miles were added in the interval. These were the commencement of the Nawoon Embankment which joined on to the 10 miles from the Nawoon to Henzada. The whole of works were however, brought up to a minimum height of 3 feet above the 1868 flood and the top was generally increased to 14 feet in width. The minimum side slope was on the outside $2\frac{1}{2}$ to 1 and on the inside 2 to 1. Fig. 2 shows the position of these works when the flood of 1871 rose against them; with the breaches which followed. The river surface rose above the flood of 1868, 1·68 feet at Myanoung, 1·04 feet at Kanoung, 0·99 feet at Shwe-gyeen; 1·70 feet at Nyoungyo and 1·29 feet at Henzada. There is here a want of parallelism difficult to account for in the surface of the two floods, but which may be due to local changes in the main or minor channels of the river near the gauges in the three years (1). It may be here mentioned that slight changes in the set of the current, in the opening out or closing of a small channel near a gauge, or in the formation of a sand bank in its neighbourhood bring often marked variations in the readings from year to year. Both Kanoung and Shwe-gyeen had large banks of sand and pebbles

Breaches in Embankment in 1868.

The 1871 flood.

(1).—The greatest discrepancy occurs at Nyoungyo. Here no less than 3 differing marks were shown for high flood in 1871; but as breaches occurring and others threatening just then in the embankment diverted the attention of the Engineer in charge it was found impossibe to verify the true mark. A brick pillar was built soon after, the highest mark (which appears slightly erroneous) being chosen.

thrown up in front of them about 1871, and possibly the low rises there may be due to this cause, the principal current having been diverted from the bank.

Breaches in 1871.

262. One breach occurred at the 18th mile, and one at the 36th mile of the Myanoung Embankment, while in several places between those miles it showed signs of weakness. The height of the flood here varied from 1 foot to 1.68 feet above that of 1868, so that in no case was the work topped by the water. The water had not risen high against the work when it was breached, and in both cases the cause as far as could be discerned was due to sandy earth or defects in the ground beneath the embankment. The Henzada Embankment was breached at the 4th mile. Here the flood of 1871 rose fully 1½ feet above that of 1868. The embankment was unusually massive, the original earth having been weak the greater slopes of 3 to 1 had been adopted here by Mr. Bennett in carrying up the work. It was alleged that white ants had bored through the bank here; and a nest had been removed from the embankment in the previous dry season at a short distance from the point of failure. But no sign of such boring was observable; and the work suddenly gave way while coolies were working close to it on the 7th August. About 50 feet of it went in a mass, the top sinking and the lower part bulging outwards. In a few days the breach widened to 400 feet, no protective measures at the ends of the work having much effect until the gap was wide enough to pass off the water as rapidly as it arrived. The water excavated a channel some 20 to 30 feet deep in the ground on the embankment line. It passed off rapidly in the bed of an abandoned stream, doing little damage to the country. These breaches are in some measure typical of many of those that have succeeded them.

The 1875 flood parallelism with the 1871 flood.

263. The 1875 highest flood stood at the following heights above those of 1871 and 1868 respectively.

Table 27.

Stations.	1875 above 1871.	1875 above 1868.
Myanoung	0·76	2·54
Kanoung	0·70	1·88
Shwe-gyeen	0·84	1·79
Nyoungyo	0·00	1·70
Henzada	1·00	2·29
Zaloon	0·52	

There is a distinct parallelism between the 1875 and 1871 floods from Myanoung to Shwe-gyeen in the straight portion of the river before described. The deficient elevation at Nyoungyo is most marked, and is in all probability ascribable to the error made in marking the 1871 flood at that place. The flood of 1875 was most accurately noted at Nyoungyo. At Henzada the rise is above the average. The gauge there is fixed in a minor channel just in front of the town, and is thus liable to share in the changes taking place continually in this small arm of the river. Probably a portion of the excess height here was due to an increased opening out of this channel at that time. At Zaloon a sand bank formed near the gauge, but has since been partially swept away.

The Kyangheen Embankment in 1875.

264. The Kyangheen Embankment, which had not been fully protective in former floods and so caused no damage through breaching, was at this time in fair working order, the sluices and the cross bund before described thoroughly reclaiming the interior. Neither it nor the Myanoung Embankment had been raised fully to the height of 3 feet above the floods of 1871, as these works were unremunerative, and hardly able to pay interest on first cost, so that

it was deemed undesirable to add much to their original expenditure. But considerable additions had been made to both at their weaker points, and as far as possible the sum of money appropriated to maintaining them in good condition was devoted to raising the crest. Otherwise they were in much the same condition as when visited by the flood in 1871. The Kyangheen Embankment suffered severely. It was breached in four places and the interior space filled with water, which remained till the floods went down again. The Myanoung Embankment was breached in one place, near the 31st mile where the work was 9 feet high with 7 feet of water against it. The water here penetrated through a sandy stratum in the ground and rose up in a pit some 30 feet in the interior. A serious fault in the construction of the embankments was here manifested. Most of the earth required for their construction has been taken from pits in the interior lower ground, which are removed at least 25 feet from the toe of the work. On the Mississippi and elsewhere such borrow pits are invariably prohibited, sometimes under severe penalties. On the Irrawaddy they have been used under direct orders from the Local Government. In good impermeable ground no harm results, but when percolation of water is possible the water may rise in the interior through pressure from without and carry away the ground under the embankment. Some breaches occurred in 1877 on the Nawoon side through these. The breach referred to on the Myanoung Embankment was stopped before September by a dam consisting of two rows of bamboo piles lined with mats about four feet apart, the space being filled with strong clay puddle. Practically little loss resulted to the interior country.

The Myanoung Embankment in 1875.

265. The works constructed from 1871 to 1875 are shown in Fig. 3 of Plate XX. They made a continuous length of the Henzada Embankment of 53 miles, and of the Nawoon work of over 50 miles. These had been raised to a uniform height of three feet above the flood marks of 1871, with an allowance for shrinkage of from $\frac{1}{6}$th to $\frac{1}{4}$th in height. But the settlement of the earth was unequal, the clayey part often changing form very much as it got wet, and bulging outwards. From 1873 to 1875 sufficient had not been done to bring these deformations of the work into correct shape. The water thus rose on the 3rd mile of the Henzada Embankment nearly to the crest, and was close to it in other places. On the Nawoon Embankment line, from causes afterwards to be discussed, the water rose very irregularly. At the entrance to the river it rose about one foot, as at Henzada, at the 12th mile to 1·76 feet, at the 25th to 1·75 feet, and at the 30th mile to 2·3 feet above the flood of 1871. In some places owing to the irregularities of the settlement in the work the flood rose over the crest, but owing to the exertions of Mr. Hallett, Executive Engineer, and the Civil authorities, aided by the villagers along the line, the works were saved from breaching, though severely tried, and under imminent danger of succumbing.

The Henzada Embankment in 1875.

266. The experience gained in this flood was most valuable. It was found that Colonel Short's conceptions of the Irrawaddy rarely rising above its banks, and the greater damage to the Myanoung plain in former days being due to the Patashin flood, were erroneous. The unknown great flood from which his heights were taken was surpassed by that of 1868; which at the time was esteemed so exceptionally great that no unusual precautions needed to be taken for a greater flood. The 1871 flood shook the faith in this notion considerably when it rose nearly an average of $1\frac{1}{2}$ feet above that of 1868; but at the same time all the papers and reports by the writer and others on that occasion prove that new anticipations were formed that then at last the very highest flood had been reached; and a somewhat unfounded belief in the capacity of the embankment to resist all future efforts of the river was formed. The excess average rise of about one foot in 1875 in the Irrawaddy above the flood marks of 1871, upset these anticipations and dispelled all belief that finality had been reached in the preparations necessary to meet such floods, The writer reported fully on all the details of the floods and the embankments

Experience gained in the 1875 flood.

on this occasion under date 1st September 1875, and strongly recommended that an entire revision of the whole works should be made, in the following extracts. "Para 19. "The conclusions to be drawn from the observations made during these floods may be briefly summarised :—

The writers conclusions drawn from observations of 1875 flood.

1st.—Efficient protection can be given during the highest floods of the Irrawaddy, if the embankment works are made sufficiently strong and kept up to their strength by proper supervision and maintenance. Before very long there will be fully 1000 square miles of cultivation behind the embankments,so that any breaches in these will lead to immense damage to crops, with possible great loss of life.

2nd.—A second conclusion therefore is, that the embankments should all be put into a thoroughly efficient state. This they never have been yet. In ordinary structures of wood or iron or masonry, a margin of strength is always provided, often 8 or 10 times the required strain, and never is it considered safe to give less than five times. In these embankment works where failure is of such incalculably greater import, the margin of strength has always been very narrow ; and in some cases, as that of the Kyangheen embankment, it has been *nil.* The lower part of the Myanoung embankment from the 17th to the 44 miles, and a few miles of the old portion of the Henzada embankment are deficient in this excess of strength. The breaches that took place in 1871, which were then declared to be through no defect in supervision or maintenance prove this and they have not been strengthened since. No efficiency of supervision, indeed, can compensate in any way for inherent weakness of structure or defects of design. When the floods rise no great amount of labour is available, as all the people are cultivating ; and little earth is obtainable, owing to the presence of water everywhere. The success of the new embankments has shewn that a higher rise than anticipated can be met when a little extra strength is given. It is the more necessary now, since the projected embankments on the left bank may raise the surface of the river. I would therefore strongly recommend that the whole of the embankments in the division be now brought up to a height of three feet above the flood of August 1875, that a top width of 14 feet be given, with slopes of at least 2½ to 1 and 2 to 1. Where the earth is weak and sandy greater slope should be given. I will submit estimates for this work. The necessary measurements have already been ordered.

3rd.—The third conclusion is, that nothing should be spared to bring up the staff of the division to the highest degree of efficiency. The work is one of extreme responsibility. A failure on a road, railway or a building entails only the loss due to replacing the work, with some inconvenience ; but a failure on an embankment brings with it not only the same loss and the same inconvenience, but may bring wide-spread devastation, with ruin to a population, and terrible loss of life. Every person in immediate charge is put upon trial in the event of a failure, which often happens through causes beyond his control, but which might sometimes be prevented. Trustworthy and energetic Officers alone should be selected for this work, which should be made one of honor and advantage, as it is one of danger and responsibility. I would particularly urge these points on the Chief Engineer's notice

at the present time when additional help is required in the division, both for the re-construction and strengthening of the old work, and for the erection and preparation of new. Competent Assistant Engineers are now wanted; the present staff of subordinates being sufficient, except that two or three Sub-Overseers are required.

4th.—A fourth and last conclusion is, that an Embankment Act is now imperatively necessary. It should first provide for hindering wanton or careless damage to the embankments themselves, or the structures connected with them; and secondly, should provide for securing a sufficient supply of labour in extraordinary emergencies. No country in the world, where large embankments are properly kept up, is without such legal provisions, nor can they be dispensed with here. The interests involved are too grave to be longer left to chance. The people, in the great majority of cases, appreciate the works, and are anxious that they should be kept efficient; and are not unwilling to aid. But malevolent and lazy persons damage the works, or hinder, by their example, their neighbours from assisting, by themselves holding aloof, and thus throwing all the work on the better disposed. By regulating the conditions under which such help may be resorted to, security can be taken against doing so unnecessarily. There will be no disposition to do this, if proper payment is secured for work done, at higher rates than ordinary in such circumstances."

Colonel Oliphant the Chief Engineer's recommendations and observations.

267. On receiving that Report Colonel Oliphant R. E., the Chief Engineer of Burma at the time, said on the 23rd October 1875, in the Revenue Report for 1874-75 :—"Considering the great anxiety and risk experienced this year, especially on the Henzada line of works, I consider it to be absolutely necessary that all the embankments should be raised to fully 3 feet above the flood level of this year, I would prefer, myself, a free board of 4 feet to provide for wear and tear, and the estimate to be prepared for this purpose should be debitable to "Capital Account." Even if Rs. 3,00,000 had to be spent on the work, it would be money well laid out, as the additional annual interest of Rs. 13,500 would easily be covered by the progressive increase of revenue.

"The experience of all former floods shewed that the slope of the flood surface between Thayetmyo and Henzada increased with the height of the flood. In the years 1873 and 1874 when the level of the highest flood at Thayetmyo was 8 feet below that of 1871, the differences, at Prome, Myanoung, and Henzada, were respectively about 6, $3\frac{1}{2}$ and $1\frac{1}{2}$, whereas this year, the surface slope has been the same as in 1871, or if anything somewhat flatter near Henzada. On the Bassein river, there has been a considerable afflux at Myogwin, near the junction of the Ngawoon and Thambyadine streams, caused, I believe partly by the embankments, and partly by the much greater extent and depth of spill which now passes out from the Irrawaddy by this channel, owing to the high bank having been eroded away since 1871 :—

If, as I have stated, this remarkable feature of afflux in the lower reaches of the river, during the present year's flood, be due to the construction of the Henzada embankments, I would seriously warn the Government of India against the construction of similar works on the eastern or left banks of the river, until the consequences of such a measure have been most thoroughly investigated.

"I myself do not think that the effects of such works would be much felt in the districts below Donabyoo and Nga-thain-gyoung, in years of ordinary flood, but I am perfectly convinced that the most disastrous consequences would ensue, in such years of flood as 1871 and the present one. All the lower part

of the Delta below Donabyoo would be entirely submerged, by the 2 or 3 feet additional rise of flood, which would probably follow upon the construction of an embankment for 100 miles on the eastern bank."

"Even, if only the first or upper section of 25 miles in length be determined upon, as necessary for the reclamation of land near the Railway, we must calculate upon an affiux of between 6″ and 9″ on our present line of works, so that I do not think it would be safe to allow a less free board than 4 feet above the level of this year's flood, for the revised crest of the existing embankments, as already recommended in para 29. In fact, I should advise that, in the first instance, only the creeks and depressions communicating with the Irrawaddy be closed up as a tentative measure, leaving the construction of the bank for exclusion of spill, for further consideration."

"I trust that, in making these recommendations I may not be looked upon as an alarmist, but when we find the high flood of 1871, reported on all hands by the people of the country to have been a most unusual one, so soon displaced from its post of pre-eminence, I think it must be admitted that the utmost caution should be exercised in the extension of embankment works on the Irrawaddy.

"As this is probably the last report I shall submit upon the financial results of these works, I need hardly apologise for endeavouring to impress upon my successor and every one else concerned in the matter, my own conviction of the necessity of placing our finished sections in absolute security, before undertaking any further extensions, and that every step in advance should be made with the utmost caution, so as not to imperil either the vast interests now protected by our works, or those, of perhaps even more importance, existing to the southward and westward of them."

The Honorable Rivers Thompson's testimony and recommendations.

268. The Chief Commissioner, the Honorable A. Rivers Thompson, in his minute on that Revenue Report, remarked (5th November 1875) "Since the year to which this report refers was closed we have seen the highest inundation as yet recorded of the Irrawaddy river. Floods which seem to have prevailed in every part of India and indeed in other parts of the world have found a place in the History of British Burma also; and the extraordinary rise which has to be recorded this season is noted at every station along the river, as the highest that has been known in the memory of the inhabitants. I had occasion to pass up the river at the highest point which the flood had reached, and both on the Ngawoon, along the left bank of which the embankments extend as far as Ngathaingyoung, and all up the right bank of the Irrawaddy to the point at which the embankment commences the same fact is forcibly and prominently noticeable, of the protection and security to life and property which the embankment has given to those within its alignment.

"The effect was the more remarkable, from the contrast which the desolation on the opposite or unprotected banks of these rivers presented. No one who had not had ocular demonstration of the scene, could ever realize the difference in the position of residents on the two sides of the rivers. It was not only that one side was for miles inland submerged, and that the flood water had destroyed by submersion the young nurseries of plants on which the riverine villages depended for their season's crops while within the protected banks there was generally a wide expense of rich cultivation wherever a village was visible; but in many other respects, the personal safety, comfort and wellbeing of the people within the embankments were so manifestly greater. Their houses and cattle were safe from risks. Their ordinary avocations were followed without distraction or disturbance, and they were not exposed to the perils and inconvenience of a life in boats or on the top of such houses as the floods had spared.

"As regards the work for the season immediately before us, I concur with the Chief Engineer in thinking that, with the experience of the dangers we have recently passed through, it should be directed to the strengthening and raising of the whole line of embankment."

269. These extracts give, in the most forcible manner, the impressions made on those who were directly responsible for the works, and foreshadow the subsequent policy pursued with regard to them. On the one side, if we leave out the Kyangheen embankment, a wholly insignificant and unprofitable work, then in an undue state of weakness, which brought about its failure; the whole of the main embankments then existing, with a total length of nearly 150 miles, suffered only one small breach, which caused almost no damage, as it opened into a low uncultivated tract near the lower end of the Myanoung embankment, although the river rose to heights of from one to three feet above the great flood of 1871, itself unprecedented, and surpassing that of the highest known previous flood by an average of 0·75 feet. The one prominent fact demonstrated was thus the absolute success of the embankment works under an exceptional and unanticipated strain. But those who saw the works and the risks run, were more impressed by the inadequacy of the preparations which had been made to withstand such trials. It was evident on the one side that greater floods than any within experience might come down the river; and while the narrow escape the whole of the district had from submersion through the averted failure of the works showed the value of the margin of safety provided; it also proved on the other side that that margin was too small and that to remove further danger from a recurrence of such floods a considerable raising and strengthening of the whole system was required.

Resume of impressions made by the 1875 Flood.

A complete revision and strengthening of the works necessary.

270. Detailed plans and estimates were accordingly prepared for completing the works as above proposed, with a free board of 3 feet above the high flood mark of 1875; a top width of 14 feet; and side slopes of $2\frac{1}{2}$ to 1 on the outside and 2 to 1 on the inside. The estimated cost of carrying out these alterations was 3,04,646 Rs. divided as follows:—Kyangheen embankment 9 miles long, area protected 6 square miles, 38,565 Rs; Myanoung embankment $44\frac{1}{4}$ miles long, area protected 200 square miles, 90,904 Rs; and the Henzada embankment, at that time in all 103 miles long protecting land estimated at 800 square miles, 1,75,171 Rs. The necessity of carrying out these works was concurred in by the Government of India and by the Secretary of State for India; but it was not recognized that it was a work of urgency, probably owing to the confidence inspired by the actual resistance of the works to the 1875 flood; and a further extension of the works on the Ngawoon river side for 29 miles was ordered to be gone on with simultaneously with the carrying out of the raising works. No special addition of money for the purpose was given; and thus instead of the whole line of existing embankments being put into thoroughly good order in one season the expenditure was so distributed as to extend over four working seasons in making the necessary additions to the height and strength of the works. The amounts actually spent on these raising and strengthening works including further additions on the Nawoon side are as follows:—

Detailed Plans and estimates of cost for additional works.

	1875-76.	1876-77.	1877-78.	1878-79 to January 1879.
Kyangheen embankment ...	9,988	5,540	13,342	4,194
Myanoung embankment ...	22,580	13,303	35,309	9,684
Henzada embankment ...	62,603	54,609	61,483	26,997
Total ...	95,171	73,452	1,10,134	40,875=3,19,682 Rs.

271. As far as possible the money spent in each year was devoted to those points which were weakest, and, as a matter of fact, almost the whole allotments for the two financial years 1875-76 and 1876-77 were spent in the one working season of the beginning of 1876, as this season generally lasts from December to June; and the dividing date of the years is the 31st March. On the Irrawaddy the flood of 1876 was not higher than usual; and none of the works were disturbed in that year; but on the Ngawoon side an exceptional local rain-fall came down; and as the new extension of the embankments here brought the work to the $70\frac{1}{2}$th mile,

Progress of strengthening works.

passing one point of the river—Paya-gyee—where a spur of hill from the Yomas runs down to the river's edge on the right side, all the spill was shut into the channel; the two causes combined to destroy a large part of the newly thrown up and unfinished works. Urgent representations were made after the 1876 flood regarding the desirability of providing further large sums in time especially for the Nawoon side, and a sum of Rs. 50,000 was allotted, but the sanction reached Henzada too late on 27th January 1877, to be of use, as the work people had mostly gone home, and could not again be gathered so late in the season.

The 1876 flood.

272. The above works were thus in the following position when the 1877 flood came down the river. The Kyangheen embankment was about half raised; the heavier portions of the work from the 4th to the 8th miles receiving the greatest atttention, and being made thoroughly secure. The lighter portion running through the town of Kyangheen and the north of it was partially raised; a light breastwork being thrown up in front so as to permit the body of the embankment to be used as a town road. The work had not been carried to the full height in any part; nor had the small cross-work running from the elevated interior ground been raised at all. Extensive additions were made to the Myanoung embankment, especially to the weaker places; but it had in only a few parts received its full height of 3 feet above the 1875 flood. The Irrawaddy portion of the Henzada embankment was raised everywhere almost to the full height and strength. Some of the upper length of the work on the Ngawoon side was raised to the required height; but it was far from complete, while beyond closing the breaches of 1876, nothing whatever was done after the flood of that year previous to that of 1877. The extent of the works in the latter year is given in Figure 4, Plate XX.

The 1877 flood. The positions of the several works.

273. The flood of 1877 was marked by the peculiar phenomenon of a double rise whose origin and general form and volume have been already discussed in the earlier part of this Report. We have now to consider only the forms the flood waves assumed on their passage down the river relative to the previous floods and to the embankments. The 1875 flood and the first and second flood wave crests of 1877 took the following heights at the several stations:—

The two high rises of the 1877 flood.

Table 28.

Stations.	1875.	1st of 1877.	2nd of 1877.	Difference of 1st and 1875.	Difference of 2nd and 1875.
Saiktha	77·86	78·94	79·74	1·08	1·88
Myanoung	70·91	71·26	71·87	0·35	0·96
Shwe-gyeen	61·34	61·75	62·08	0·41	0·75
Nyoungyo	53·77	53·95	54·10	0·08	0·33
Henzada	43·48	43·63	43·78	0·15	0·30
Zaloon	35·99	36·41	36·42	0·42	0·33
Donabyoo	24·47	24·30	24·43	—0·17	—0·04

The first wave crest passed Saiktha on the 11th August, reaching Zaloon 101 miles off on the 15th, and Donabyoo on the same day. The second was at Saiktha on the 19th and at Henzada, Zaloon, and Donabyoo on the 21st, the rate of travel being thus twice as fast with the latter as with the former. It has been explained that the peculiar sharp form of the wave crest as shown on the Myanoung gauge and discharge diagrams, was due to the extreme high flood having been generated in the neck of the Irrawaddy basin by exceedingly heavy local rain-fall precipitated into the river on top of an already flooded channel. Colonel Oliphant remarks on the parallelism of the 1875 flood with the previous ones, on the whole length of the channel; and, contrasting this with the ordinary

The 1877 flood contrasted with that of 1875.

flood range at the stations from Thayetmyo southwards, is inclined to think that the embankments tend to perpetuate, throughout the lower channel and delta, local elevations of surface in the channel above. This flood of 1877 in both its rises refutes the idea. In the first rise of 11th-15th August, the elevation of 1·08 feet at Saiktha has become 0·35 feet at Myanoung; and 0·15 feet at Henzada. Some peculiarity of the Zaloon gauge caused it to record a relatively higher rise at this period. As will be seen in discussing the question of surface slope at Saiktha and Myanoung, a local set of the current may alter a few inches the relative readings of gauges a mile or two apart; and it is probably due to a set of this kind that the Zaloon record reads higher than the others. The disasters on the Nawoon, and the general supervision of the works during flood occupied the attention too much to permit this anomaly to be studied at the time. The Donabyoo gauge shows that the surface was actually lower here than in the 1875 flood.

The reservoir action of the channel in the 1877 flood.

274. The true explanation of this progressive diminution of the height of the flood wave in 1877 in passing down the river, is found in the comparitively slight degree in which the channel had been filled previous to the arrival of the wave. The discharges for June, July and August of the three years 1871, 1875, and 1877 were at Saiktha, in tons:—

The 1871, 1875 and 1877 flood waves.

Months.	1871.	1875.	1877.
June ...	44,536,288,000	45,354,290,000	31,489,828,000
July ...	88,977,031,000	94,027,284,000	66,882,183,000
August ...	102,173,848,000	109,506,570,000	122,604,180,000
Total ...	235,687,167,000	248,888,144,000	220,976,191,000

The masses of water brought down in June and July were in 1871, over 133 billion tons; in 1875 over 138; and in 1879 only 98 billion tons, so that the storage capacity of the river channel from Saiktha southwards must have been largely occupied by the earlier flood waves before that of August, always the greatest, reached this part of the channel. The gauge readings bear testimony to this. In June 1871 the Myanoung gauge recorded 30·33 feet; the Henzada one 32·83 feet. In July they reached 37·92 and 38·29 feet respectively; the latter months figures indicating a channel already brimming over throughout its length. The June figures of 1875 for the same stations are 34·25 and 35·83 feet; the July ones 36·25 and 37·50 feet; and though a subsequent fall of from 2 to 3 feet enlarged the capacity of the channel for more water, the whole of the lagoons, and minor channels had been filled previous to the August flood arriving. In 1877 it was different. The flood diagrams in Plates IV and V, present the features of the different floods in a convenient form; but the Myanoung and Henzada gauge figures give clearly the relative positions of the channel. These figures are, for June, 25·02 and 27·95 feet respectively; for July, 32·33 and 34·25 feet being the highest points touched: The interval of 11 days in the beginning of August during which the first flood rushed down past Saiktha was occupied in filling the channel between that place and Henzada and Donabyoo. The slow progress of the wave of 101 miles in five days on the first occasion evidences this. On the second occasion the small mass of the wave causing the excess elevation of the surface relative to the total discharge passing down, enabled it to be absorbed or spilled over the banks in its passage downwards; so that on reaching Donabyoo the river surface remained lower than in 1875. The quick passage of the second wave is remarkable. It traversed 130 miles in two days.

Results to the works of the different forms of waves.

275. A study of these figures brings forward the important fact that while the most dangerous flood wave for the upper embankment works is one of high crest generated in the river immediately above the delta, this is by no means so threatening to the lower delta works as a moderated wave from

higher regions of possibly slightly lower crest, but filling the channel steadily before its highest point passes down. In considering therefore the possible results of a still greater flood than any yet experienced a distinction must be held between a rapidly formed one of high rate of discharge coming on to a channel only half filled, and floods of greater magnitude but less intensity or rate of discharge, which result from the progressive increase of the rain precipitation over all parts of the Irrawaddy Valley to form a series of waves whose crests unite to reach the delta simultaneously on an already filled channel. The chances against such an event as the last occurring are indefinitely greater than the former; and if the works are adequate to meet such floods as those of 1875 and 1877, they may fairly be accepted as strong enough, the margins of strength recommended by experience being provided, to meet any such future floods as untoward combinations of the normal meteorological conditions may reasonably be expected to send down. Of course no provision can or should be made for possible abnormal atmospheric states, such as a cyclone passing over the valley with numerous water-spouts might bring.

The Kyangheen Embankment in 1877.

276. The preparedness of the different works for meeting the 1877 flood has been stated. The Kyangheen Embankment was again unfortunate; but this time not so much from the Irrawaddy rise, as from a tremendous local precipitation of rain on the hills behind the town. This rainfall was part of the general fall over the delta and neck of the Irrawaddy Valley already described (Part II). No measurements of this for Kyangheen are available; probably it reached 5 or 6 inches of rain in one day on the hills. At all events, a great rush from the hills filled the Patashin choung to overflowing, and a few smaller streams directed their discharge to the back of the horse shoe bend of the embankment, and it came immediately upon the small cross bund which had been erected to divert the light local drainage through a 6′ by 3′ sluice. The work had not been raised or strengthened, and gave way; the interior area was filled; and, subsequently, similar rainfalls occurring behind the northern end of the lighter part of the work, a portion of this was damaged. The heavier work in the low ground stood throughout. Had all the proposed alterations been made it is probable the embankment would have altogether resisted. These are since almost completed, and it is hoped no further trouble will arise to this small embankment. It is not considered necessary to raise this work to 3 feet above the new datum supplied by the 1877 flood; but the original estimate covers the cost of making the heavier work 2½ feet, and the lighter 2 feet above that level.

The Myanoung Embankment in 1877.

277. The Myanoung main embankment suffered no inconvenience from the 1877 flood, although the projected raisings had not been completed; and, in parts, from the 19th to 21st mile the water rose nearly level with the crest. The works are liable to leak slightly; but as a rule the leaks are small, and so long as the water comes clear and in small quantities no precautions are needed.

Method of supervision during floods

Before the floods rise all jungle and grass are cut closely from the top and from the inner slope and berm of the embankment works; so that the slightest trace of infiltration or percolation can be seen at once. Gangs of men numbering from one per mile to five, or even more, are regularly employed to keep the grass down and the work in good condition; and they are distributed in high flood along the embankment to watch for any signs of weakness. A Sub-overseer or Lower Subordinate Officer is placed in charge of a portion ranging from 10 to 20 miles, and an officer of the Upper Subordinate or Engineer establishment of lengths from 20 to 40 miles according to the nature of the task. It is incumbent on all in charge to be constantly inspecting and supervising the work, more particularly as the flood is rising; as then the cracks in the ground, or white ant or rat perforations are easily discernable, before the swelling of the earth has partially closed them. When leaks of great magnitude are apparent much depends on the nature of the soil as to the method to be adopted in closing them. White ant passages in clayey soil are easily plugged with clay or larger rolls

of matting rounded into balls and rammed in from the *inner side* of the work. Some leaks are controlled by forming an earthen wall round them so as to permit them to flow freely; but, through raising the surface and diminishing the pressure, the flow is checked and the earth is not cut away. Larger leaks in similar soil from cracks must be stopped from the outside by puddling the front under the water, or by a row of light sheet piling, or by massing heavy clayey earth on the whole front where the leak can be supposed to open. If the soil is stiff and strong, the embankment may be half cut through while the flood is actually up, and the weak place refilled with puddled earth; but this remedy is dangerous where the water stands above 8 feet in height. If the work is very heavy and high, and clayey, it may suffer deformation under the pressure and commence to roll inwards, at the same time leaking. Several instances of this occurred on other parts of the works. The only remedy then is, as earth in large quantities can rarely be got, and of itself is insufficient, to carry several rows of piles parallel with the work, one commencing in the berm inside the embankment, another near the toe of the work, and others at intervals of from 4 to 6 feet along the inner face. The piles have to be common jungle wood, some 6 inches in diameter and ten to fifteen feet long. They should be driven from 3 to 6 feet into the earth, and connected with strong bamboo matting above. The object of these rows is to in a measure counteract the rolling tendency of the clayey mass. The tops of the piles should be connected transversely from row to row; and all earth that can be got is then to be carried up evenly from the innermost row to the top of the work, which continues gradually to sink. Fortunately this rolling never takes place except with the strongest clayey earth; and no reasonable mass seems entirely to prevent it. It depends on the cracking of the earth, and the penetration of the water through these cracks, the faces of which become slippery and allow the whole work to move. No accident has as yet happened with these parts; but much anxiety and cost have been caused.

Completion of strengthening of Myanoung Embankment.

278. The Myanoung Embankment has since, in the heavier portions, been gradually brought to an even height of from 2½ to 3 feet above the 1877 flood. In no part has it been allowed to remain below 2 feet over that level. A sum of 10,000 Rs. still remains to be spent on the work during the year 1879-80, which will make it finally secure against even extraordinary floods, except so far as unforseen accidents may render it liable to fail. The Marginal Embankment was breached in two places without loss to life or property and has been removed to a more secure position about 150 feet from the rivers edge, where it was being undermined.

Henzada Embankment in 1877 Irrawaddy branch.

279. The Irrawaddy branch of the Henzada embankment had had most of the work provided for completed before August 1877. It was considerably stronger in every part than it had been in 1875. It was everywhere raised to 3 feet above the high flood line of that year; and the slopes had been strengthened to the full dimensions of 2½ to 1, and 2 to 1. The telegrams from Myanoung announced the danger there, from the first rise of the 11th August; and the writer proceeded to that place meeting there the Chief Commissioner and his staff. On returning to Henzada it was with some surprise that he learned that a breach had occured on the retired position of the embankment at the 23rd mile, above Zaloon on the night of the 15th August. The Zaloon gauge on that day presented the anomalously high record of 0·42 feet above the 1875 flood, above noted. It is just possible that the changes in the direction of the stream due to the large curve above Zaloon altering its position slightly may have induced a high local rise extending to the 23rd mile; but this cannot now be established. But the work was well 2½ feet above the then flood height. The water stood some 12 feet against it. The ground is there of a somewhat mixed nature, of sand and clay; but care had been taken to move all sand from the site, and to use only good firm earth in throwing up the work. The breach occurred in the middle of the night; with no previous

Branch of the 23rd mile.

leak apparent. The villagers say a mass of the embankment was pushed out instantaneously, some 50 feet wide, and a body of water poured through. The houses are all on wooden posts; a front lower room being about 3 feet from the ground, the back sleeping room standing from 8 to 12 feet from the ground. This is the invariable plan of all native Burmese houses. The lower rooms and outhouses were swept away; but no harm resulted to the people; and only two cattle were lost. The breach speedily widened to 600 feet, with the water running through from 8 to 12 feet deep. Very little excavation of the ground occurred. This breach, which was the sole one occurring on the whole line of the Irrawaddy main embankment in 1877, was one of those which must be entered as an accident, depending on unforeseen contingencies, such as weakness in the ground. With this exception the whole works stood. The cost of preparing them for this strain in excess of that required for the 1868 and 1871 floods was comparitively slight, though the high flood discharge had risen from about 1,440,000 cubic feet per second in the former year to over 2,100,000 in 1877; with a rise of surface averaging above 3 feet throughout the length of the channel. There is thus no ground to be dissatisfied with the results of the works on this side. The Nawoon works require separate and special consideration.

Questions remaining to be answered.

280. The examination to which the relations of the existing embankment works on the Irrawaddy with the great floods of 1868, 1871, 1875 and 1877 have been subjected leads to the following questions. 1°:—How will the present works, considered as extended to Pantanaw, be affected by the cutting across of the Thambyading bend? 2°:—What result will follow to the present works in case a still greater flood than any of those considered, say one of 2,500,000 cubic feet per second, should pass down the Irrawaddy at Myanoung? 3°:—What indications do the present data give of the probable results of embanking the Irrawaddy on its eastern bank from Talokmoh to Yandoon? The mere statement of these questions is of high practical value if, even without obtaining answers, it should direct further attention to the grave problems involved; and which doubtless will receive solutions on some points within the next ten years. It is ominous, however, that the second question should have 2,500,000 C. Ft. per second subsituted as the probably extreme highest flood ever to be expected, in place of the 1,450,000 C. Ft. per second assumed ten years ago by Colonel Stoddard for a similar question, from his calculations of the flood of 1868. Only approximate answers can be expected, and as this part of the Report has already run to excessive length, these will be concisely stated.

The first question relating to the Thambyading cut-off.

281. The first question has already been partially answered in anticipation in discussing the cutting across of the Thambyading bend. The water in the river channel will be lowered for similar discharges at Nyoungyo and Loodauzoo, by about $2\frac{1}{2}$ or 3 feet; and there will be a corresponding rise, at any rate for the first few years after it takes place, in the neighbourhood of Sarawa and Henzada. It is possible that the lowering of the river surface will extend over the 42 miles of channel reaching from the top of the bend to Myanoung; though there it will be hardly perceptible. It is likely again that the rise on the southern side of the bend will reach to below Zaloon, some 24 miles off; but will probably very little affect the river near Donabyoo. There will be a neutral point about Thambyading, or more probably the Nawoon entrance, where the surface will be neither raised nor lowered. These anticipations, not wholly conjectural, but deduced from the available figures, which are fairly complete, are represented in feet above M. S. L. by the following figures relative to the 1875 and 1877 floods.

Table 29.

Stations.	1875 actual.	Flood anticipated after cut off.	1877 actual.	Flood of 1877 anticipated after cut off.
Saiktha	77·86	77·86	79·74	79·74
Myanoung	70·91	70·91	71·87	71·87
Kanoung	68·07	67·07	...	...
Shwégyeen	61·34	59·34	62·09	60·09
Nyoungyo	53·77	50·77	54·10	51·10
Henzada	43·48	46·48	43·78	46·78
Zaloon	35·99	37·49	36·41	37·91
Donabyo	24·47	25·47	24·43	25·43
Setkaw	19·00	19·00	...	...

The dotted line in Plate VIII represents the higher of the figures at each station (1).

Extreme limits of the change of river surface anticipated.

282. This line and these figures give approximately the heights of the river surface, if after the cut-off occurs exactly similar floods to those of 1875 and 1877 again come down. The distance from Nyoungyo to Henzada is, by the river channel of 1877, 32 miles. The cut-off will shorten it at first, by about 15 miles, making its distance 17 miles. The fall in 1875 was 10·29 feet, in 1877, 10·32 feet. If we give the average fall of 4 inches to these 17 miles, the total fall will be about 5½ feet from Nyoungyo to Henzada after the operation. A deduction of 2½ feet from the Nyoungyo level and an addition at Henzada of the same give nearly the required heights as above. The other stations are proportionately altered. It is to be understood that these figures represent nearly the extreme limits of the changes ensuing; and that in the very worst conditions. The new channel will soon begin to lengthen, and the relative heights to alter: and though they may never again reach the present figures, there will be an oscillation in future between those above given.

Changes and preparations to be made in the embankment.

283. The embankment works should, to be adequately prepared for the change of surface levels with floods like those of 1875 and 1877, be raised and strengthened in the part reaching from the Nawoon entrance to Danabyoo. A very slight raising would be necessary, particularly with the marginal works, if only a recurrence of those floods were to be met. The 1875 flood proved, when it rose almost above the crest of the Henzada and Nawoon Embankments in several places, that the section given to the works is strong enough to bear the pressure of water against them to their own height. And it showed that there is time to take the precautionary measures of raising the top when the water threatens to rise above it. The Henzada Embankment on the Irrawaddy side is now about 3 feet above the 1877 flood in its heavier portions throughout, and is nowhere less than two feet. It will be made to a minimum height of free board of 3 feet throughout, relative to the highest flood lines. And this might possibly suffice to meet the anticipated elevation of river surface near Henzada if we could be secure that no greater flood should ever come down.

The second question. What height of work is necessary to meet a 2¼ million flood?

284. But with our past experience of the great floods, and our knowledge of the conditions on which the flood formation depends, it would be unwise to let things remain as they are. We have thus to consider what elevation of the river will ensue if, first, an assumed maximum flood volume comes down previous to the cut-off, and secondly subsequently to the cut-off. The discharges of the river at Myanoung are for the four great floods :—

1868	1,445,000 Cubic Feet per second.
1871	1,672,500 „ „ „ „
1875	1,883,600 „ „ „ „
1877	2,040,000 „ „ „ „

(1).—A gap has been left to represent the shortening of the river channel through the cut-off.

Without remarking on the good fortune for the embankments attending these floods coming in the order of progressive increase they show, it is sufficient to note that the total difference between the flood of 1868 and that of 1877 is nearly 600,000 cubic feet per second; and the progressive increment for the three intervals is thus about 200,000 cubic feet per second. When we consider the exceptional circumstances attending the last flood generation, it might seem sufficient to assume another such increment for a still greater flood. In order to be safe, however, let two such increments be taken, and we have a flood discharge of 2,500,000 cubic feet per second. What rise under present circumstances would this discharge induce in the river's surface?

The rise at Myanoung over 1875 flood will be about 3 feet.

285. It may be remembered that the discharges have been mostly calculated from the Myanoung gauge register by a scale constructed graphically and numerically from the Saiktha measurements. This scale extended by successive increments formed by the same parabolic law on which the scale is constructed, gives a height of little more than 43 feet on the gauge as the height required at Myanoung to discharge 2,500,000 cubic feet per second. The super-elevation of surface above the 1875 flood would thus be 3 feet at Myanoung; and 2 feet above that of 1877. The next question to consider is, would the surface be equally raised at the lower stations; would the new flood surface be parallel to any of the former ones? The probability is that, if this conjectural flood wave were formed as those of 1871 and 1875; that is, by a concurrence of all the causes in regular course, first forming preliminary flood waves in June and July to fill the main and minor channels of the river from Mandalay to the sea; and on top of these the August flood were generated by a combination of all the sources of flood sending down at once a high and broad flood wave whose greatest discharge reached 2½ million cubic feet per second at Myanoung; there would be a continuous elevation of the surface through the delta to the same amount as at Myanoung. But if the wave partook of the nature of the 1877 one, a sharp and local though extensive downfall of heavy rain being thrown into the river in the neck of the basin on top of a Mandalay-Bhamo flood rise on a previously unfilled channel, there is every prospect that, as in 1877, the height of the crest would be much reduced in its passage down the river.

The changes in a 2½ million flood due to the cut-off.

286. It is quite possible that both these cases might occur; but it is very improbable that either of them ever will. And the chances, as already pointed out, are indefinitely against the former contigency; as so many con-causes must enter precisely at the right time. We would thus be reasonable in looking forward to such an enormous flood wave progressively lowering as it passed down the river; and, considering the manner in which the Henzada embankment stood in 1875 with less than the same margin above the 1871 flood, which the works have now above that of 1877, it would not be incurring an outrageous risk to leave them of their present dimensions, provided the cut-off does not take place. But as this is a certainty, and likely to occur between 5 and 10 years hence, provision should be made for it. The works near Henzada should be raised 5 feet above the 1877 flood, with proportionate strength. From Henzada southwards the height might decrease to 4 feet at Donabyoo. This work is not urgent; and is only calculated for the double contingency of the cut-off and a 2½ million cubic feet flood. When carried out, the portions retired from the river should not be raised. Where the line has been retired and the river has ceased acting upon it, a new marginal embankment can be raised on the later-formed high bank. The work will be less costly and will be far safer than the retired lines, which should be looked upon as temporary palliatives for an evil. Probably not more than 8 to 10 miles of such new line will be required, but it will remove all fear of such breaches as took place on the 23rd mile in 1877. There is always sufficient warning in erosions to permit removing the works in time.

Provisions to be made.

287. In treating of the Henzada Embankment it is assumed to be extended to Pantanaw. Complete plans have been sent in, in detail, for this extension, which cannot possibly raise any new engineering difficulties, but which will considerably enhance the protective value and pecuniary profits of the existing works. The length is 24 miles, of which 14 miles are on the Irrawaddy river, passing through Setkaw, and the remainder turns down the right bank of the Pantanaw river to Baudee. It is raised four feet above the highest flood marks of 1877 to provide for all contingencies of river surface elevation. Its cross section is the usual one, 14 feet broad on top, $2\frac{1}{2}$ to 1 slope outside, 2 to 1 inside. Its cost is estimated at 247,415 Rs. It will protect 150 square miles of the interior lands; and will lower the interior flood water height from $24\frac{1}{2}$ feet above mean sea level to about 11 feet. The drainage of this tract will be considered in connection with that of the whole area.

The Pantanaw extension.

288. Above the Thambyading bend, where the two actions of the conjectural flood and the cut-off tend in opposite directions; it may well be doubted whether any additional precautions should now be taken in view of a possible flood of $2\frac{1}{2}$ million cubic feet coming down. The margin of strength and the freeboard formerly advocated have now been given; and the funds at disposal are sufficient to complete the works thoroughly with height of about 3 feet even above the flood of 1877. Any short comings in this respect through settlement of earth can be met from the funds provided for maintenance. The excess elevation of surface to be apprehended from such a flood will not bring it above the embankment crest in any part, unless through local exaggerations of rise. And the work, which is now thoroughly consolidated, has shown itself so strong during the 1875 and 1877 floods that the remainder of the additions to be given to it should provide a margin of strength sufficient to enable it to withstand even so great a flood as that contemplated, coming down before the cut-off occurs. After this has taken place the danger will be much lessened, as the surface from Myanoung southwards will be lowered. The chances are great against such a flood as that considered ever taking place; they are much greater against it occuring within the next five years, so that by ensuring a state of thorough preparedness to the work, by levelling it before and after every flood season, and bringing up all deficiencies of height or strength of section to proper form, the Myanoung Embankment may be left in its present state with a reasonable assurance of safety. Its continuation to the entrance of the Thambyading river should be carried at an even rate of surface fall from the Nyoungyo height of crest, to a height of 3 feet above the 1877 flood mark at that place.

Few further precautions necessary to Myanoung Embankment.

289. The Kyangheen Embankment is now secure against even extraordinary floods of the Irrawaddy, but local storms like that of 1877 are beyond the sphere of calculation. If the present repairs had then been effected, however, the work would have stood, and we may now hope that it will prove a useful and trustworthy work, even if it is financially unsuccessful.

The Kyangheen Embankment.

SECTION X.

The Irrawaddy Channel and Double Embankments.

Difficulties in the way of answering the question as to the effect of double embankments.

290. The furnishing an answer, even of an approximate or conjectural nature, to the enquiry as to the probable results of embanking both sides of the 150 miles of the Irrawaddy channel from Saiktha to Yandoon, is so difficult a task that little will now be attempted but to give a clear idea of the problem, and the nature of the solution proposed. We have, by an excessively tedious course, at last arrived at some determinate notion of the actual conditions furnished by nature, under which the task must be undertaen, or leftk alone. Some of these conditions must be accepted as they exist; no alteration or mitigation being possible by human agency. Thus, it is an absolute condition that the line of the eastern embankment must follow generally the narrow margin of high land found on the left bank and marked on the maps as bounding the flood channel; and must neither deviate to follow the main channel line over the later alluvion as proposed by Colonel Stoddard, nor must it be retired to the low interior lands behind. It would be much better, in every respect, that no such work should be built than that it should follow either alternative. There can, neither, be any changes brought about in the amount of flood naturally brought down to the delta. In some discussions on river embankments, proposals have been made for storage reservoirs, intended to accumulate water in the flood season, thus lessening the discharge to the river, and subsequently permitting it to flow in the dry season. No such measures can have any effect on the Irrawaddy floods. Indeed it may be doubted whether the progress of cultivation in the hilly regions will alter much or at all the discharge delivered to the delta. The sources are mostly remote; and the monsoon supply is incommensurably greater than the modifying agencies.

Doubtful advantage of works to regulate the Irrawaddy.

291. It is a moot point whether the natural oscillations of the main channel within the flood channel, or encroaching on the permanent bank, are subject to human control. That they are capable of being modified temporarily admits of no doubt; but that permanent success can attend any efforts, however well judged or costly, to definitely regulate the whole channel the writer cannot believe; and he considers that it must be accepted as a fact, to be sooner or latter counted with, that all the oscillations now in progress will work themselves out in much the same way whether they are interfered with or not. The proposed embankment line must thus reconcile the opposed conditions of following the high permanent bank, and of allowing room for erosions when the river makes a set against it. So far as the past experience for 16 years on the western side of the river serves, this task will be by no mean a difficult one. If we suppose it overcome, and the line to be definitivelys chosen as indicated the remaining natural conditions may be examined.

Boundaries of the channel to be encased.

292. The portion of the Irrawaddy channel to be affected by the construction of the proposed works is thus contained between Saiktha to the north and the entrance to the Pantanaw river to the south; and is bounded to the west by the existing embankment works, considered continuous except au the Thambyading and Nawoon openings; and on the east by the proposet embankment works. Cross sections of this channel have been taken at inted vals of a few miles apart, generally normal to the course of the stream (but ir- a few cases not quite so). These are given, with the exception of a few taken

in the neighbourhood of the Thambyading bend, where some confusing elements occur, in Table 30 below. The cross-sections are numbered in succession from Saiktha southwards; and their distances from that place measured along the 1877 *thalweg* are shown in column No. 2. The width of the main channel as measured from top of bank to top of bank is given for each section in column 3; and the total width across the river from the one permanent bank to the other in column 5.

Sections of river.

293. A comparision of these widths with the plans permits the situation of each cross-section relative to the direction of the channel to be understood. It was not always possible to hit off a line normal at once to the complete flood channel and to the main one; and some alterations of direction were requisite in order to bring the line of section nearly at right angles to the main channel. The main channel width is of far more importance than the remainder; as in this the principal part of the high flood water and all the mean flood and low water pass down the river. The width of this progressively diminishes from the portion of channel above Henzada to Yandoon. In the upper part it averages over one mile in width. Lower down it ranges from 3,000 to 4,000 feet wide. The remainder of the flood channel, for convenience called the minor channel, (using the word in a different sense from the *lit minor* of French hydraulicians) also diminishes in width in the lower half of the channel. A seeming deviation from this rule is seen in the last two sections, which have been carried some distance over broken ground on the east bank. The true permanent bank is really much nearer the main channel than shown, and the depressions included in the flood channel appear rather due to excavation of the surface than to abandoned channels. With

Widths of main channels.

The minor channels defined.

Table 30.

Shewing width and area of Irrawaddy Channel proposed to be embanked.

1	2	3	4	5	6	7	8
No. of cross section.	No. of mile of river channel South of Saiktha.	Width of main Channel.	Width of minor Channels.	Width of Total flood Channel.	Area of main Channel.	Area of minor Channels.	Total Area of High flood Channel.
1	1	5,000	3,000	8,000	255,259	17,224	272,474
2	13	3,000	13,800	16,800	148,417	235,935	384,352
3	16	4,100	12,500	16,500	203,100	128,420	331,529
4	20	5,000	14,000	19,000	187,787	144,507	332,294
5	24	6,200	6,800	13,000	221,040	106,354	327,402
6	28	5,600	9,900	15,500	248,593	113,512	362.105
7	33	4,000	9,000	13,000	170,867	130,893	301,760
8	37	6,000	23,000	29,000	229,463	206,987	436,450
9	43	6,300	22,700	29,000	212,523	285,407	497,930
10	55	7,000	22,000	29,000	296,964	230,368	527,332
11	78	4,600	18.400	23,000	213,837	149,178	363,015
12	83	7,200	6,800	14,000	229,935	39,925	269,860
13	87	6,700	2,300	9,000	170,113	52,424	222,536
14	93	6,000	11,000	17,000	266,644	12,200	388,653
15	97	3,000	19,000	22,000	174,386	145,918	320,304
16	101	5,000	17,000	22,000	185,920	92,522	278,442
17	107	5,000	7,000	12,000	186,552	59,735	246,287
18	114	4,300	14,700	19,000	155,553	112,341	267,894
19	117	8,000	6.000	14,000	120,930	166,389	287,319
20	122	5,700	2,300	8,000	148,928	68,447	217,375
21	128	6,000	1,300	7,300	162,799	47,770	210,569
22	135	3,000	2,400	5,400	149,740	4,736	154,476
23	137	4,000	2.600	6,600	146,496	27,810	174,306
24	141	2,900	10,100	13,000	147,240	67,765	215,005
25	143	3,600	3,400	7,000	164,708	16,045	180,754
26	148	3,000	12,000	15,000	145,424	71,933	217,357
27	152	3,600	15,400	19,000	143,676	60,522	204,198

this exception there is a gradual diminution in width both of the main and flood channels on the river course southward, and a corresponding restriction of the space over which the flood waters can spread, when both sides of the channel are embanked. This fact acquires less importance, however, when it is seen that in no part of the course is the width much less than at Saiktha, where the main and minor channels are 8,000 feet across. It is rather to be esteemed a fortunate circumstance for the proposed embanking that the lateral variations of the river have excavated the very broad flood channel shown from the 13th to the 117th miles, where it varies in width from 13,000 to 29,000 feet as a rule, giving room for the expansion and storage of the flood waters.

Great width of flood channel favorable for embanking.

294. The storage capacity of the channel, as far as that is indicated by lateral expansion, is more closely given by the whole surface area of the space to be reserved to the channel after the embankment works proposed are completed. As the measuring stations for discharge in 1872 and 1873 were chosen at Saiktha and Zaloon, the latter place being the southern termination of the embankment work at that time, and situated 101 miles lower down the main channel than Saiktha, the river surface between those stations has been accurately measured out from the large maps, and has been found to approximate nearly to 305 square miles. This is the area within which the flood can accumulate between the two stations. From Zaloon southwards to Yandoon the area may be more roughly estimated at about 60 square miles. If, as is nearly the case, it be assumed that the general level of the upper surface of the alluvial plains and sandbanks is covered when the flood waters reach from 36 to 37 feet on all the gauges, any excess flood elevation finds a very large room for expansion in the 365 square miles of open flood channel thus available for it between Saiktha and Yandoon.

Area of surface of flood channels Saiktha to Zaloon.

Zaloon to Yandoon.

295. At lower levels it can only expand in those portions of the main and minor channels open to the water at each height of gauge. Table 30 gives the areas of the main and minor channels, and of the totals or flood channels, at each cross-section. These have been calculated out from the 1875 flood line. Sufficient distinction has not always been made in this Table for the cases where the river is in course of change from one main channel to another, as in the section on the mile 13th and others. The larger channel has alone been entered as the main one, the smaller being classed with the minor. A reference to the plans will prevent any error arising from this. It is not intended to deduce any practical inference for immediate use from these figures; and only round numbers will be now employed. The figures given show the importance of the main channel compared with the others, however extensive these may be. At Saiktha it is over 250,000 square feet; the minor channel, which only receives water at 37 feet on the gauge being 17,000 square feet. In only one other case, at the 87th mile, does the main channel reach this area, and that by including a lesser channel in its area; but from Saiktha to Zaloon (101st mile) it averages over 200,000 square feet. South of Zaloon the main channel averages nearly 150,000 square feet. There is a corresponding, or even greater, diminution in the minor channel area in the southern part of the course considered. The complete flood channel in the upper half runs generally from 300,000 to 500,000 square feet in area, while from Donabyoo to Yandoon it ranges from 150,000 to somewhat over 200,000.

Areas of main and minor channels.

Complete flood channel areas.

296. The function of these minor channels as moderators of the greater floods can best be understood by considering them in their relation to the gauge readings. All the space included below low water mark of 1877 and the bed of the channel is occupied by water at the lowest seasons; and though this is comparatively insignificant, and may be neglected, it is the space

The minors channels as flood moderators.

between that low water surface and the high flood surface which acts as the storage reservoir. As the diagrams of the gauge readings for the floods years indicate, the rise from low to high water varies at the different stations. At Saiktha and Myanoung it is about 42 feet to 1875 high flood. It thence progressively diminishes towards the sea, being, as shown in the longitudinal section (Plates IX to XVIII), about 41 feet at Nyoungyo; 37 at Henzada; 33 at Zaloon and 24 at Donabyoo. Nearly all the minor channels come into play above these lowest heights of gauge. If a sufficient number of cross-sections had been taken (and more are available than those given, but it is hardly necessary to show them) the storage capacity of the channel could be accurately calculated for each height of gauge. No useful purpose would be served by this; and it is sufficient to note roughly, that if we assume the areas of the minor channels above Zaloon to average, as approximately they do, 132,000 square feet, which is 1/200th of a square mile (10/2112ths) we have on a channel length of over 100 miles a storage capacity from extreme low water to high water of 1875 of about ½ a cubic mile between Saiktha and Zaloon in these channels.

Great effect of minor channels on wave crests.

297. When the water rises in the river it flows over the lower sands and through the openings into the lagunes of the minor channels, where it is at first stagnant or moves slowly downwards. Rising still higher the capacity of these increases rapidly and the water takes a more decided velocity, which continues to increase till at highest flood it sometimes is comparable with that in the main stream, though it rarely exceeds one half of this on an average. These minor channels thus form important adjuncts to the main channel in passing down the water at high flood; as well as in temporarily receiving and holding up the ½ cubic mile of water. This amount is a large one; but its value appears to diminish very much as a mitigating agent of acute floods when it is remembered that on different occasions, in the high flood of 1875 and 1877, more than one cubic mile of water came down in a single day. But it is hardly in modifying the greater mass of the discharge that this storage capacity acts. The main channel as will presently be seen exercises a much more powerful moderating action on the mass of the wave. The minor channels cut off and receive the crest of the rising wave, and hold it back, until the greater mass passes. It is only the extremely high crests of the flood waves which do damage to the country and to the embankments. And it is principally with the higher crests of the waves that the reservoir action of the channels come into play. On examining the whole of the cross sections it will be found that the major part of the storage space of the flood channel, excluding the larger secondary channels of the river, is only made available when the river surface rises high on the gauges; its greatest capacity as aforesaid being developed where the sand banks and alluvial plains are wholly submerged and the 305 square miles of river surface between Saiktha and Zaloon are freely opened to the outspread of the flowing waters.

The secular surface of the river; and the flood wave crest.

298. If we call the line described by the river surface in a succession of days at a fixed gauge like Myanoung the secular surface of the river, it is seen on studying the diagrams of the flood waves that the crests rising above the average secular surface form a very insignificant part of the whole mass discharged, and that if the main channel can adequately dispose of the principal mass the minor channels can excrcise a most important influence on the remainder. The history of the flood waves of 1875 and 1877 illustrate this. Their various features and the conditions attendant upon them have already been described at length. It would encumber this report too much to give the various gauge readings for these and other waves, and with a few figures a reference to the diagrams in Plate III IV and V may suffice. On the first of August 1875 the gauges read as follows'

The 1875 flood wave.

Saiktha	Myanoung	Shwegyeen	Nyoungyo	Henzada	Zaloon	Donabyoo
32·25	32·75	34·66	35·37	25·71	26·17	38·04

These figures show that the channel was already well filled; a flood wave of

July having reached 36·25 at Myanoung on the 16th; and to higher points at the lower stations. The Donabyoo gauge varied only 0·87 feet during July, from 38·83 at the highest to 37·96 at the lowest, while at Myanoung the variation was from 36·25 to 32·21, thus showing already the reservoir action of the channel in operation. But a considerable space of channel must have been still available; nearly 8 feet at Saiktha and 4 feet at Zaloon, for 305 square miles. Taking a mean of 6 feet, and assuming all to be clear, the capacity of the whole flood channel from Saiktha to Zaloon was then somewhat under $\frac{1}{3}$rd of a cubic mile; which taken at 4168 million tons left space for about 1,400 millions. When the whole of the gauges rose to highest flood mark of 40 feet from the 17th to the 21st August this space was filled, and only gradually discharged its mass past Donabyoo, where there was little change in the surface for several days, while the upper gauges fell rapidly, that at Saiktha reaching 34 feet on the 27th.

The 1877 flood waves.

299. The various gauges stood at the following heights on the 22nd and 23rd July 1877.

Saiktha.	Myanoung.	Shwegyeen.	Nyoungyo.	Henzada.	Zaloon.	Donabyoo.
22nd	22nd	22nd	22nd	23rd	23rd	23rd
24·29	24·98	27·41	28·25	28·90	30·67	32·50

From 11th to the 15th August the gauges rose to the following heights with the passage of the first wave

11th	12th	12th	13th	15th	15th	15th
41·08	40·35	40·41	40·08	40·15	40·42	39·83

the rise occupying from $16\frac{3}{4}$ feet at Saiktha to $7\frac{1}{3}$rd at Donabyoo. The whole flood channel available here was not proportionally extensive with the former space; but was evidently large enough to reduce the crest of the flood wave by over half its height in its downward passage of 137 miles. The second crest of the wave from the 19th to the 21st reached the following heights

19th	20th	20th	20th	21st	21st	21st
41·88	40·96	40·75	40·33	40·30	40·33	39·96

which in the lower parts are barely in excess of the first wave crest height. This appears the more remarkable as the channel was already filled, and the velocity of the wave was great in its transit. But a second moderating agent was brought into action with the higher floods; and it is the determination of this which is the principal object of the investigation, and which is surrounded by the greatest difficulties.

The spill from the river channel over and through the banks.

300. A considerable amount of water is lost to the river channel in its course from Saiktha to Yandoon. On the right bank are the Thambyading and Nawoon Rivers, and the open bank from Loodauzoo to Thambyading. The former river is open all the year round; the latter at mean flood when the gauge reads about 30; the bank not being topped till the water is marking 36 or so at Henzada. On the east bank the Teandau and two or three smaller, but still large, creeks, open into the Hline at mean flood; and numerous small ones at high flood. When the river is about 37 on the Myanoung gauge and 38 at Henzada there is a spill on the left bank. It is obvious that these losses of water will act most efficiently on high crests of the greater flood waves, in reducing their height and moderating their intensity. In this the spill acts conjointly with the moderating capacity of the channel at present. But when a continuous embankment is made on the left bank from Talokmoh to Yandoon, and the whole of the openings to the Nawoon, or all of them but the Thambyading, are closed, as it is intended that they shall be, this element of the moderating action will cease; while in the measure that the high flood surface of the river is raised that of the storage capacity of the channel will increase. It is thus necessary in order to estimate the probable results of embanking the both sides, to determine how far each element at present contributes to the modification of form now witnessed in the passage of a flood wave down the river.

The volumes of the wave crest standing above 39 feet on the Myanoung gauge.

301. Recurring again to the 1875 and 1877 waves, as exhibited in the diagrams and in the tables, it is seen that the crests of the waves which do all the damage are comparitively small in their mass. From the experience we now have it appears that a flood wave reading 39 feet on the Saiktha and Myanoung gauges can be disposed of by the river channel without any harm resulting.

The daily discharge with this gauge reading averages about 4,000 million tons. Higher gauge readings with greater discharges imply danger to the embankment works. In 1871 these figures were only exceeded for three days, from the 5th to the 7th August; the total quantity of water carried in the crest of the wave above 39 feet gauge being about 209,455,000 tons. In 1875 this excess was greater. The surface stood above that gauge reading for eight days from the 13th to the 20th August. The crest of this wave contained 2,781,483,780 tons. The first flood wave of 1877 lasting for the 10 days from the 9th to the 18th August carried 4,486 million tons in its crest standing above 39 feet. This is somewhat over one cubic mile. The second wave crest for the three days 19th to 21st August contained 2,033 million tons above the 39 feet mark.

302. These quantities, and not the total discharges, are the ones most to be considered in providing sufficient capacity in the new flood channel to be comprised within the embankment works. There is one circumstance connected with the flow of water of the very highest importance in facilitating the transit of additional masses of water thrown in on top of already filled channels, such as would result from confining the present spill water of the Irrawaddy to the flood channel, and that is, the rapid increase of velocity which takes place in the whole mass by comparatively slight increases in the height of the volume moved. Explain it as they may, and on the explanation depends the whole theory and science of hydraulics—hydraulicians are thoroughly agreed as to the fact, which has been proved beyond contestation in every experiment on record. When the Irrawaddy discharge was measured at Saiktha in 1875 it was found that the mean velocity of the river, which averaged about 6·5 feet per second when the gauge stood at 36 feet, rose to nearly 7·5 feet per second as the water reached 40 feet. The same increase of velocity with increased depths is discernible at all the lower parts of the river course; and it is to be observed that, while in the lower half of the part under consideration the width and area of cross section of channel are very much restricted compared with those in the upper half, the depth of the channel is very considerably increased, and there are few or no bars across it. Thus a third agency, highly favourable to the proposed undertaking, is introduced, which principally affects the main channel and the great mass of the water conveyed by it, but which must also have its effect upon the contribution of the wave crests in their downwards passage.

Provision has to be made for the high flood wave crest only in the embanked channel.

The importance of the increase of velocity with the increase of depth of flowing water.

303. The main channel itself performs a double function in passing the flood waves down, and in moderating by its own storage capacity the form and volume of each wave at the successive points. Altogether there are four modifying agencies which should be separately determined beforehand both as to the manner and amount of their action before the difficult question of the results ensuing from the double embankment can be even approximately answered. These agencies are:—

Four principal modifying agencies on wave crest in the flood channel.

1st.—The changed discharging power of the main channel in different parts of its course due to changes of form in width and depth.

2nd.—The storage capacity of the main channel.

3rd.—The storage capacity and varying flow of the water in the minor channels.

4th—The influence of the spill over and through the banks and channels of this part of the river. Others modifying agencies, such as the excavating action of the water on the channel changing its form and varying its capacity, and such events as the contingent cut-off at Thambyading, should enter into consideration.

304. Sufficient has been said in an early section of this part of the report on the uncertainty ruling in hydraulic science both as to the true theory and the best formula for the flow of water. Theories can be dispensed with if only we have workable formula which can express, within the range of experience and for some short distance beyond it, the correct results

The problem presented is that of permanent varying flow of water; no formula for which of practical value has been devised.

of observed facts. No such formula has obtained general acceptance for the very simplest case of natural flow, that on a single given section of a river of regular form, with all the attendant conditions of slope, cross section, wetted perimeter, &c. accurately known. And it is only by introducing arbitrary empirical elements that the best formula existing can be made to represent nearly the conditions of flow on regular artificial channels of uniform section and slope. It has, nevertheless, been attempted to devise formulæ which shall represent all the complex results of the changes of flow between different sections of a natural channel of varying forms and dimensions, with continually changing volumes of water discharged. The problem is called that of permanent varying flow in distinction from that of uniform flow, at once the easiest and simplest problem, where all the failures have occurred. It is needless to say that no advance whatever of the slightest value to practical science has been made by mathematical enquiries in solving the problem. The influence of the numerous modifying conditions (some of which, as changes of channel-lining, generation and loss of living force, excavation and deposit, &c. have not been enumerated here) have not been stated out nor considered; and it is impossible that any arrangement of terms and factors prescinding all such conditions can satisfy the wants of practice.

Only methods of direct observation can be utlized in solving this problem.

305. No further reference will, therefore, be made to such formulæ or *a priori* methods of solution; and those only which can commend themselves to the practician will be considered. A distinction must be made of these into what is desirable and what is practicable. Thus it would be eminently desirable to know from direct observation both for ordinary floods and for extreme high floods such as those of 1875 and 1877 the volumes of water passing down the river continuously at several different cross sections throughout the length of the channel; for choice, say at Saiktha, at Myanoung, at Shwaygheen, Nyoungyo or Loodauzoo, at Henzada, Zaloon, Donabyoo, and Setkaw. Nothing could be better adapted than a study of the changes in the volume of water passing these stations, within the channel, as they actually occurred, to lead immediately to a close fore-knowledge of the changes to occur when the double embankments are complete. But, in the first place, an examination of the many cross-sections and of the plan of the river will at once prove that it would be practically impossible to measure the discharge simultaneously on the main and minor channels at most of these places. On the whole length of the delta channel very few situations offer themselves where such measurement is practicable, and those principally in the lower part. One, however, is noticeable opposite the town of Yaygheen, the value of which is greatly diminished by the immence shelving sandbank to the east and by the fact that in no part of the river have greater changes been continually taking place than here. Possibly, now, as these are less in amount, the station is eligible. Just below Henzada, at Oukyuaglay, there is a suitable place, which was used by the writer in 1869; but very great changes have been, and are still in progress here, the east bank having been considerably cut away. In 1872-73 the river measurements were made for the lower station at Zaloon. At that time this was the end of the embankment works, and though there is an immense sand bank with minor channels beyond it opposite the town, the bank is high and well above mean or even ordinary flood water, and it is only in very high floods that the minor channels there act. The river did not rise above these banks in those years, nor was any noticeable quantity of water lost by the minor channels; so that the experiments made are good. In 1875, however, it was found that the situation had become unsuitable; and after trial for a few weeks it was abandoned. Opposite Saga-gyee there is a comparatively narrow flood channel. But, for some years, the river has been carrying away the bank under the town in such a manner as to entirely preclude this being used as a station. In 1875, on abandoning Zaloon, the lower station was tried at Donabyoo, and for two or three months observations were made. But after changing the cross-section once or twice it was found that though the main channel could be measured, there was too much difficulty with the minor ones. The observa-

The desirable and the practicable measuring stations.

tions are useful in a measure, but are unsatisfactory in comparison with the Saiktha results for 1875. Below the present termination of the embankment, 5 miles south of Donabyoo, the channel is much more regular, and several stations can be chosen.

306. Then, secondly, intervene the question of cost and available skilled observers. Overseer Shere Mahomed, whose services have been invaluable throughout, and whose zeal and intelligent aid merit special recognition, has had charge of the whole of the observations made at Saiktha; but the continuous observers at the instruments were educated and trained men, assisted by sub-overseers. Two observers were required with two or more boats; and the cost of floats and incidental expenses brought the total expenses to from Rs. 200 to Rs. 300 per month, at high flood, for the one station. In low water the task was easier and fewer boatmen were requisite. The cost, in itself, was not great; but the difficulty of providing trained men for the observations at flood time, when the services of the whole staff were urgently required for supervising the embankments, stood in the way of extending the observations as much as could have been desired. Sub-Engineer Henry, however, was able to control the Zaloon observations, which were taken directly by himself, or by subordinates under him. His valuable services also call for particular notice, as the work entailed severe hardship and continuous application in addition to his own onerous duties on the embankment during flood. It is to be remarked that, owing to the want of a sufficient trained staff, the Zaloon observations were not so complete, especially in the number of subsurface observations taken in 1872 and in 1873, as could have been desired. The 1875 observations in the lower branch of the channel were also conducted by Mr. Henry.

The cost of measuring the river discharged.

Overseer Shere Mahomed's observations at Saiktha.

Sub-Engineer Henry's observations at Zaloon.

307. The intention, in taking the discharges of the river at Saiktha and Zaloon, was to interpolate, by suitable formula deduced directly from the observations, calculated discharges at the stations above enumerated, where gauge registers of the height of the river show the oscillations of the surface at each flood. This work required an investigation concerning all existing formulæ, and their suitability; firstly, in representing the discharges actually obtained for the Saiktha and Zaloon Stations, in terms of the river slope, cross-section, wetted perimeter &c, hitherto employed; and, secondly, in extending their use to represent the variations in the heights of the surface at the intermediate stations, when the river should be encased completely from Saiktha to Yandoon. It led to the discussions on the theory of the flow of water in natural open channels before referred to. The subject opened up a most extensive field for study; and, though it was found possible to take up a definite position as to the requisite formula and the theory of the flow of water at an early stage of the enquiry, it was also found that before either of these could be employed as contemplated, the entire question of the hydrography and the hydrology of the river would have to be considered and stated out. The floods of 1875 and 1877 proved the necessity of gathering and collecting all available information on those points; and this has been done, less with a view of solving the problems presented than of directing attention to the immediate requirements to our store of knowledge which can most easily be satisfied, and which are indispensable to any rational solution. The Report, so far as written, has been constructed in a directly reverse method to that in which it is presented. The data obtained in 1872-73 were worked out mostly at the same time as gathered, and though they have been subsequently revised and elaborated, could have been given in their present form long ago. But the insufficiency of this mode of dealing with the question became more conspicuous the more the matter was studied; and the partial and imperfect nature of the means and data at our disposal was made manifest by the changing condition of most of the elements intended to enter into the calculations. The Saiktha cross-section, though it retains with much permanence

The procedure actually followed in the enquiry has been the reverse of that presented in this Report.

its original features been changed in important respects by the raising of the Kyangheen bar. The Zaloon section changed widely in form in a single year; and at present has little resemblance to what it had when the first observations were made. The Thambyading and Nawoon river entrances have undergone a succession of changes, now increasing, now diminishing the afflux of water. The high bank cut away south of Loodauzoo has permitted the spill discharge to vary widely from year to year in that part. The alterations of rise and fall in the river surface, actual or contingent, due to the Thambyading bend, change the condition of the problem continually, and indicate that any solution must be general, and must include the extreme variations to which the flood surface is liable from such causes. The successive increases in the heights of the 1875 and 1877 flood above that of 1871 most unmistakably show that any solution which might have been offered from the whole of the data at disposal previous to their appearance would have been valueless or misleading unless it included a large conjectural element. It is of much higher importance to have come to a due appreciation of the imperfection and insufficiency of the data than to have assumed them as complete, and proceeded to deduce definite conclusions from them.

The data at present available are of very great value.

308. The data are, nevertheless, of exceedingly great value, and the writer believes it possible still to give an approximate answer to the principal questions from them. It is intended that the further Report shall deal with the materials gathered to that end. By generalizing the formula from the Saiktha and Zaloon observations, and extending the calculations to all or part of the stations mentioned, it will be possible to find the height to which a $2\frac{1}{2}$ million cubic feet per second flood would rise above the highest known or probable flood surface (before and after the cut-off), if it were entirely contained within a hard unyielding Channel. The amount and method of disposal of the spill waters to the Hline and the Nawoon are subject to calculation. And all the other modifying influences, the excavations of the channel, the changes in height of surface through formation of bends and cut-offs can be in a measure allowed for, even where not accurately calculable. And it is noticeable that the enlargement of the channel though excavating, the increased reservoir action of the main and minor channels through embanking, which are not directly susceptible of calculation, all tend to mitigate the consequences of shutting in the spill waters to the channel of the Irrawaddy.

The quantities of water entering leaving the channel above Zaloon.

309. Without now entering into the close detail which must be brought forward in considering the effect of shutting in the 1875 or 1877 flood to the channel; it will be of much interest to examine the actually observed results of the passage of ordinary floods such as those of 1872 and 1873, which do not rise above the permanent banks of the river, and thus have little spill water lost, on their passage down the channel. A certain amount of water is lost to them through the Teandau and other smaller creeks on the east side, mostly above the flood height of 26 feet on the Myanoung gauge and through the Thambyadeing and Nawoon entrances on the right bank. If, on the one side, all the water entering the portion of the channel between Saiktha and Zaloon were known, and the quantity leaving it through the Zaloon cross-section, and by the Nawoon river entrances also, the differences of these sums would give exactly the loss though the left bank. The difficulties attendant on the determination of these various quantities in the most favorable conditions of a low ordinary flood not rising over the banks will afford proof of the greater difficulties attendant on the more complex question of the floods which spill over the river banks throughout its course.

Shewing measured discharges of the Irrawaddy and Nawoon Rivers in 1872-73

	Date.	Gauge Reading.	I. Saiktha.	Gauge Reading.	II. Zaloon.	Gauge Reading.	III. Thabingyo.	Difference of I & II+III.
August 1872.	1	30·66	2,593,000,000	...	*a*2,885,300,000	37·10	191,953,000	− 484,253,000
	2	30·33	2,436,400,000	37·25	*a*2,885,300,000	36·80	186,935,000	− 635,835,000
	3	30·41	2,602,400,000	37·00	2,793,900,000	36·55	172,014,000	− 363,514,000
	4	30·33	*a*2,591,660,000	36·67	2,708,050,000	36·45	*a*161,222,000	− 277,662,000
	5	31·83	2,894,000,000	36·33	2,687,600,000	36·46	166,643,000	+ 39,757,000
	6	32·83	3,028,000,000	36·08	2,772,700,000	36·72	193,294,000	+ 62,006,000
	7	33·41	3,117,100,000	36·04	2,685,300,000	37·10	197,681,000	+ 234,119,000
	8	34·33	3,165,200,000	36·13	2,686,500,000	37·46	200,963,000	+ 277,737,000
	9	34·58	3,210,200,000	36·21	2,756,200,000	37·70	230,046,000	+ 223,954,000
	10	34·75	3,240,400,000	36·54	2,765,400,000	37·89	229,931,000	+ 245,069,000
	11	35·00	*a*3,225,200,000	36·88	2,866,000,000	38·02	239,108,000	+ 120,092,000
	12	35·00	*a*3,101,000,000	37·08	2,795,200,000	38·12	249,495,000	+ 56,305,000
	13	34·83	3,081,700,000	37·17	2,816,300,000	38·20	248,210,000	+ 17,190,000
	14	34·41	3,009,200,000	37·29	2,795,700,000	38·30	254,750,000	− 41,250,000
	15	33·75	2,923,500,000	37·38	2,833,000,000	38·23	226,127,000	− 135,627,000
	16	33·25	2,871,900,000	37·46	2,942,500,000	38·15	220,456,000	− 291,056,000
	17	33·00	2,704,700,000	37·46	2,883,400,000	38·09	216,853,000	− 395,553,000
	18	32·83	*a*2,673,200,000	37·46	2,870,900,000	37·96	217,107,000	− 414,807,000
	19	32·75	2,658,400,000	37·42	2,870,900,000	37·82	209,310,000	− 421,810,000
	20	32·91	2,800,500,000	37·33	2,878,100,000	37·74	216,153,000	− 293,753,000
	21	33·16	2,938,200,000	37·25	2,885,300,000	37·74	225,549,000	− 172,649,000
	22	33·41	*a*2,948,200,000	37·17	*a*2,785,085,000	37·76	229,738,000	− 66,623,000
	23	33·75	2,978,200,000	37·08	2,696,000,000	37·83	226,164,000	+ 56,036,000
	24	34·16	*a*3,059,200,000	37·13	2,697,500,000	38·12	228,148,000	+ 133,552,000
	25	35·00	*a*3,225,200,000	37·17	*a*2,700,892,000	38·36	228,018,000	+ 296,290,000
	26	35·16	*a*3,234,200,000	37·33	2,707,676,000	38·47	229,530,000	+ 296,994,000
	27	35·41	*a*3,291,200,000	37·42	2,711,492,000	38·52	233,896,000	+ 345,812,000
	28	35·66	*a*3,301,200,000	37·58	2,718,700,000	38·54	226,394,000	+ 356,106,000
	29	35·83	3,391,200,000	37·75	*a*2,720,100,000	38·58	244,313,000	+ 426,787,000
	30	36·00	3,509,300,000	37·83	2,720,800,000	38·61	246,601,000	+ 541,899,000
	31	36·00	3,527,800,000	37·92	*a*2,856,824,000	38·67	247,003,000	+ 423,973,000
	Total	...	93,331,560,000		86,378,619,000		6,793,655,000	159,286,000
September 1872.	1	35·83	*a*3,488,500,000	38·00	*a*3,009,850,000	38·70	247,797,000	230,853,000
	2	35·50	3,468,200,000	38·00	*a*3,009,850,000	38·67	245,671,000	212,679,000
	3	35·08	3,311,100,000	38·00	3,009,850,000	38·62	246,682,000	54,568,000
	4	34·25	*a*3,118,700,000	38·04	3,020,300,000	38·54	234,349,000	− 135,949,000
	5	33·50	2,945,000,000	38·17	2,927,300,000	38·38	232,157,000	− 214,457,000
	6	32·83	2,912,500,000	38·04	2,943,350,000	38·20	223,791,000	− 254,641,000
	7	32·33	2,855,100,000	37·92	2,952,020,000	37·95	214,384,000	− 311,304,000
	8	32·08	*a*2,720,500,000	37·67	*a*2,911,545,000	37·70	212,471,000	− 403,516,000
	9	31·83	2,686,900,000	37·33	2,853,250,000	37·50	205,484,000	− 371,834,000
	10	31·58	2,669,600,000	37·17	2,987,560,000	37·33	192,224,000	− 510,184,000
	11	31·50	2,639,600,000	37·08	2,774,300,000	37·48	195,114,000	− 329,814,000
	12	31·75	2,591,600,000	36·96	*a*2,763,288,000	37·55	194,568,000	− 366,256,000
	13	31·66	2,583,000,000	36·92	2,759,900,000	37·48	187,363,000	− 364,263,000
	14	31·41	*a*2,573,700,000	36·83	2,684,700,000	37·42	189,374,000	− 300,374,000
	15	31·08	*a*2,573,100,000	36·75	*a*2,663,806,000	37·28	184,677,000	− 275,383,000
	16	31·00	2,572,300,000	36·67	2,640,300,000	37·08	188,489,000	− 256,489,000
	17	30·66	2,501,700,000	36·58	2,632,037,000	36·92	180,130,000	− 310,467,000
	18	30·16	*a*2,403,700,000	36·50	*a*2,622,742,000	36·82	179,134,000	− 398,176,000
	19	29·58	2,290,700,000	36 42	2,614,480,000	36·73	171,995,000	− 495,775,000
	20	28·66	2,254,700,000	36·25	*a*2,532,405,000	36·44	164,675,000	− 442,380,000
	21	27·75	2,181,400,000	36·08	2,450,330,000	35·95	149,090,000	− 418,020,000
	22	26·58	*a*2,070,600,000	35·75	*a*2,410,245,000	35·31	138,300,000	− 477,945,000
	23	25·33	1,952,300,000	35·33	2,370,160,000	34·54	128,155,000	− 546,015,000
	24	25·50	1,950,900,000	34·75	*a*2,334,962,000	33·68	122,790,000	− 506,852,000
	25	26·50	2,143,400,000	34·25	2,299,765,000	33·27	122,993,000	− 279,358,000
	26	28·00	*a*2,213,800,000	33·33	2,239,800,000	33·43	131,678,000	− 157,678,000
	27	28·83	2,325,500,000	32·50	2,397,745,000	33·92	143,208,000	− 215,453,000
	28	29·75	2,362,400,000	32·83	2,327,100,000	34·45	153,889,000	− 118,589,000
	29	30·50	*a*2,520,200,000	33·42	*a*2,429,450,000	34·97	158,581,000	− 67,831,000
	30	31·66	2,783,200,000	34·25	2,531,800,000	35·49	172,719,000	+ 78,681,000
	Total	...	77,663,900,000		80,104,190,000		5,511,932,000	−7,952,222,000
October 1872.	1	32·25	2,921,100,000	34·50	*a*2,551,355,000	36·00	186,475,000	+183,270,000
	2	32·66	2,937,700,000	35·17	2,602,200,000	36·45	191,673,000	+143,827,000
	3	32·91	3,000,100,000	35·58	*a*2,607,850,000	36·80	200,625,000	+191,625,000
	4	33·00	3,053,500,000	36·00	2,613,500,000	37·04	201,005,000	+238,995,000
	5	33·41	3,038,100,000	36·25	*a*2,700,000,000	37·23	201,668,000	+136,432,000
	6	33·00	*a*2,920,600,000	36·25	*a*2,700,000,000	37·50	211,426,000	+ 9,174,000
	7	32·83	2,871,900,000	36·25	*a*2,700,000,000	37·70	212,185,000	− 40,285,000
	8	32·75	2,863,100,000	36·25	*a*2,700,000,000	37·36	209,014,000	− 45,914,000
	9	32·58	2,888,100,000	36·25	*a*2,700,000,000	37·31	207,043,000	− 18,943,000
	10	32·41	2,852,300,000	36·21	*a*2,676,500,000	37·28	205,861,000	− 30,061,000
	11	32·16	*a*2,794,000,000	36·13	*a*2,638,900,000	37·24	202,243,000	− 47,143,000
	12	31·75	2,698,500,000	36·04	2,601,300,000	37·18	196,816,000	− 99,616,000
	13	31·41	*a*2,640,600,000	35·88	*a*2,573,658,000	36·96	194,920,000	−127,978,000
	14	31·16	2,632,900,000	35·63	2,533,000,000	36·83	187,899,000	− 87,999,000
	15	31·08	2,607,200,000	35·54	*a*2,520,000,000	36·62	187,359,000	−100,159,000
	16	31·16	2,632,400,000	35·42	*a*2,515,000,000	36·46	181,668,000	− 64,268,000
	17	31·58	*a*2,695,100,000	35·33	2,576,400,000	36·39	181,490,000	− 62,790,000
	18	32·25	2,795,100,000	35·58	2,589,300,000	36·44	188,905,000	+ 16,895,000
	19	32·75	2,944,600,000	36·00	*a*2,655,660,000	36·64	196,482,000	+ 92,458,000
	20	33·00	*a*3,045,100,000	36·25	*a*2,700,000,000	36·94	200,322,000	+144,778,000
	21	33·25	3,145,600,000	36·33	2,709,411,000	37·11	204,821,000	+231,368,000
	22	33·00	2,871,700,000	36·50	2,729,411,000	37·28	208,561,000	− 66,272,000
	23	32·41	2,749,100,000	36·67	2,748,235,000	37·41	212,564,000	−211,699,000
	24	31·58	2,665,200,000	36·83	2,780,000,000	37·27	205,450,000	−320,250,000
	25	31·58	2,598,400,000	36·50	*a*2,708,050,000	37·04	192,626,000	−302,276,000
	26	29·41	2,350,700,000	35·58	*a*2,492,200,000	36·64	176,257,000	−317,757,000
	27	28·33	*a*2,199,300,000	34·75	2,449,040,000	36·10	159,196,000	−408,936,000
	28	26·58	1,954,000,000	33·50	2,384,300,000	35·38	146,378,000	−576,678,000
	29	25·16	1,843,000,000	32·50	2,178,500,000	34·45	130,452,000	−465,952,000
	30	23·91	1,737,700,000	31·50	2,130,500,000	33·30	118,436,000	−511,236,000
	31	21·91	1,547,200,000	30·58	*a*2,014,900,000	32·05	107,292,000	574,992,000

Shewing measured discharges of the Irrawaddy and Nawoon Rivers in 1872-73.

	Date.	Gauge Reading.	I. Saiktha.	Gauge Reading.	II. Zaloon.	Gauge Reading.	III. Thabingyo.	Difference
June 1873.	1	2·08	*a*250,646,000	8·79	*a*224,025,000			
	2	2·416	268,370,000	8·79	*a*224,220,000			
	3	2·00	277,180,000	9·29	*a*248,800,000			
	4	1·666	245,470,000	9·46	*a*255,930,000			
	5	1·645	228,550,000	8·79	*a*231,175,000			
	6	1·833	242,730,000	8·58	223,299,000			
	7	2·395	279,230,000	8·83	224,806,000			
	8	3·916	*a*348,350,000	9·17	*a*241,560,000			
	9	5·33	412,750,000	10·08	288,270,000			
	10	6·416	477,590,000	11·58	*a*333,046,000			
	11	8·75	595,510,000	13·17	380,212,000			
	12	11·25	744,520,000	15·08	*a*536,921,000			
	13	12·58	888,760,000	17·42	727,096,000			
	14	14·33	987,240,000	19·33	829,770,000			
	15	15·75	1,063,720,000	20·75	*a*930,420,000			
	16	16·79	1,183,870,000	21·83	1,006,970,000			
	17	18·25	1,269,740,000	22·92	1,132,700,000			
	18	19·58	1,432,490,000	23·50	1,212,610,000			
	19	21·33	1,587,130,000	24·83	1,384,550,000			
	20	23·416	*a*1,842,990,000	26·50	1,458,100,000			
	21	24·71	2,001,690,000	28·17	1,683,630,000			
	22	25·92	2,166,980,000	29·75	*a*1,807,640,000			
	23	26·58	2,222,990,000	31·00	1,905,140,000			
	24	27·041	2,262,050,000	31·75	*a*2,028,840,000			
	25	27·33	*a*2,279,380,000	32·33	2,124,740,000			
	26	27·75	*a*2,304,140,000	32·75	2,133,730,000			
	27	28·166	*a*2,328,830,000	33·08	*a*2,181,330,000			
	28	28·46	2,346,190,000	33·54	2,249,764,000			
	29	29·083	*a*2,448,170,000	33·67	*a*2,266,949,900			
	30	29·125	2,497,720,000	34·12	*a*2,269,495,900			
		Total ...	37,424,976,000		32,740,509,800			
July 1873.	1	29·00	2,409,480,000	34·25	*a*2,271,087,200	33·40	144,421,000	− 6,078,200
	2	28·58	2,324,420,000	34·33	*a*2,275,224,500	33·36	*a*142,029,000	− 92,833,500
	3	28·00	2,228,730,000	34·21	2,270,769,000	33·30	*a*139,637,000	− 181,676,000
	4	27·25	*a*2,100,480,000	33·75	2,262,684,000	33·15	134,853,000	− 297,057,000
	5	26·66	2,000,620,000	33·25	2,190,683,000	33·06	*a*130,055,200	− 320,118,200
	6	25·58	*a*1,965,590,300	32·71	*a*2,166,264,300	32·97	*a*125,257,500	− 325,931,800
	7	25·166	*a*1,952,110,000	32·04	2,135,967,000	31·80	115,662,000	− 299,519,000
	8	24·25	1,922,500,000	31·54	2,051,720,000	31·36	*a*112,514,000	− 241,734,000
	9	23·50	*a*1,782,940,000	31·04	1,940,107,000	30·92	*a*109,366,000	− 266,533,000
	10	22·916	1,674,280,000	30·54	1,923,337,000	30·05	103,070,000	− 352,127,000
	11	22·25	1,656,460,000	29·79	1,830,210,000	29·83	*a*99,498,200	− 273,248,200
	12	22·125	1,712,550,000	29·33	*a*1,750,046,000	29·61	*a*95,926,400	− 133,422,400
	13	23·75	*a*1,888,870,000	29·04	*a*1,699,506,800	29·17	88,782,800	+100,580,400
	14	24·54	1,974,710,000	29·79	*a*1,830,210,000	30·79	*a*104,927,400	+ 39,572,600
	15	25·71	2,145,280,000	30·88	*a*2,020,165,300	31·61	*a*112,999,700	+ 12,115,000
	16	27·21	2,258,060,000	31·96	2,208,378,000	32·43	*a*117,035,800	− 67,353,800
	17	28·42	2,382,590,000	32·96	2,260,725,000	33·25	121,072,000	+ 793,000
	18	29·75	*a*2,522,930,000	34·25	2,420,297,000	34·54	130,915,000	− 28,282,000
	19	30·25	2,575,540,000	34·79	2,623,290,000	35·35	135,164,000	− 182,914,000
	20	31·00	*a*2,581,080,000	35·50	*a*2,699,157,000	35·51	*a*146,306,500	− 264,383,500
	21	31·166	2,643,300,000	35·88	2,739,762,000	35·67	157,449,000	− 253,911,000
	22	31·25	2,704,330,000	36·13	2,758,837,000	35·75	168,755,000	− 223,262,000
	23	31·00	2,559,060,000	36·17	2,761,023,000	35·73	165,243,000	− 367,206,000
	24	30·67	*a*2,513,730,000	36·17	2,651,194,000	35·77	170,539,000	− 308,003,000
	25	30·04	2,430,430,000	35·96	*a*2,575,776,800	35·63	166,867,000	− 312,213,800
	26	28·75	2,231,300,000	35·67	2,471,684,000	35·37	159,823,000	− 400,157,000
	27	28·50	*a*2,220,510,000	35·13	*a*2,455,710,700	35·03	*a*150,236,000	− 385,436,700
	28	28·25	*a*2,219,630,000	34·79	*a*2,445,685,000	34·70	140,649,000	− 366,704,000
	29	28·50	2,220,070,000	34·71	2,443,326,000	35·01	140,886,000	− 364,142,000
	30	29·16	2,307,070,000	34·83	*a*2,449,151,000	35·27	141,131,000	− 283,212,000
	31	28·50	2,289,580,000	35·17	2,464,824,000	35·33	150,589,000	− 325,833,000
		Total ...	68,398,180,000		71,046,751,600		4,121,659,500	− 6,770,231,100
August 1873.	1	28·66	2,306,670,000	34·83	2,284,954,000	35·02	*r*149,099,000	− 127,383,000
	2	29·37	2,440,020,000	34·75	2,295,864,700	34·72	147,609,000	− 3,453,700
	3	30·62	*a*2,544,120,000	35·08	*a*2,362,662,900	34·89	*a*161,556,000	+ 19,901,100
	4	31·25	2,596,170,000	35·58	2,463,871,700	35·07	175,503,000	− 43,204,700
	5	32·33	*a*2,784,330,000	36·17	2,594,537,200	35·61	185,890,000	+ 3,902,800
	6	33·08	*a*2,914,630,000	36·75	2,660,573,700	36·12	200,716,000	+ 53,340,300
	7	33·75	3,030,520,000	37·08	2,766,793,200	36·53	213,332,000	+ 50,394,800
	8	34·17	3,097,930,000	37·42	2,764,084,000	36·82	224,275,000	+109,571,000
	9	34·42	3,205,850,000	37·63	2,787,598,300	36·99	226,283,000	+191,968,700
	10	34·64	*a*3,234,610,000	37·83	*a*2,793,301,800	37·08	*a*231,871,000	+209,437,200
	11	34·50	3,216,400,000	37·71	2,776,191,200	37·18	237,459,000	+202,749,800
	12	34·12	*a*3,147,900,000	37·71	2,782,487,000	37·18	232,772,000	+132,641,000
	13	33·37	*a*3,010,910,000	37·33	2,745,809,500	37·11	225,099,000	+ 40,001,500
	14	32·58	2,866,260,000	36·75	2,660,473,000	36·94	218,169,000	− 12,382,000
	15	31·87	2,754,650,000	36·50	2,659,930,000	36·72	208,256,000	− 113,536,000
	16	31·16	2,633,610,000	36·17	2,572,350,000	36·50	200,929,000	− 139,669,000
	17	30·42	*a*2,541,430,000	35·75	*a*2,464,359,500	36·20	*a*192,396,500	− 115,326,000
	18	30·08	2,500,510,000	35·50	2,459,602,900	35.90	183,864,000	− 142,956,900
	19	29·58	*a*2,440,050,000	35·04	2,386,678,200	35.54	173,977,000	− 120,605,200
	20	29·166	2,389,640,000	34·71	2,387,576,000	35·17	168,379,000	− 166,315,000
	21	29·00	2,419,570,000	34·54	2,377,151,000	34·94	165,666,000	− 123,247,000
	22	29·00	2,451,900,000	34·33	2,282,490,000	34·71	162,226,000	+ 7,184,000
	23	29·67	2,619,520,000	34·29	2,291,759,000	34·62	161,610,000	+166,151,000
	24	30·67	*a*2,717,930,000	34·50	*a*2,314,459,500	34·81	*a*170,652,500	+232,818,000
	25	30·92	*a*2,742,530,000	35·00	2,368,508,300	35·00	179,695,000	+194,326,700
	26	31·33	2,783,570,000	35·25	*a*2,400,289,400	35·34	190,796,000	+192,484,600
	27	31·83	2,813,600,000	35·50	2,432,070,600	35·63	195,344,000	+186,185,400
	28	32·25	2,875,100,000	35·79	2,517,768,100	35·92	199,402,000	+157,929,900
	29	32·48	3,029,040,000	36·00	2,526,673,500	36·20	203,877,000	+298,489,500
	30	32·66	3,074,420,000	36·21	2,576,135,300	36·44	211,913,000	+286,371,700
	31	32·66	*a*3,074,420,000	36·29	*a*2,580,727,100	36·51	*a*211,115,500	+282,577,400

310. Table 31 gives the results of the measurements made at Saiktha and Zaloon on the main river and at Thapangyo on the Nawoon, for the flood months of the years 1872 and 1873. The Saiktha measurements were most complete throughout. From 30 to 60 surface floats were observed, and ten series of floats were measured at intervals of one metre from surface to bottom on the same vertical lines. The cross-section of the river was taken from time to time and found to change but little. The calculations for the whole of the discharges on this cross-section were made by the writer from the results of the observations. The figures actually obtained are given in Table 30 in ordinary numerals; while the interpolations have been made bv arithmetical proportion from the heights of the gauge readings for the days when no observations were taken.

The table of measured discharges. Saiktha measurements.

311. The Zaloon observations were not made as often, and were not nearly so complete as the Saiktha ones. For some months only two or three of the vertical curves of velocities could be taken; instead of the ten series ordered and required as at Saiktha. An examination of these few taken shows that they give, especially in 1872 when the deficiency was most marked, a somewhat higher ratio of the lower velocities to the upper than is found in the Saiktha observations, and on the same section in 1873, and a further comparision of the discharge, as worked out for the three months of 1872 with the three of 1873, proves that this has resulted in a higher rate of discharge being shown in the former year for the same gauge reading than in the latter. The mode of calculation of the discharge was identical for the whole of the observations at the different cross-sections, and in the further Report full examples of the method will be given, but for the present it need only be said that every attempt was made to ensure accuracy; and the figures actually obtained from the observations have been employed without alteration, even were open to criticism or amendment. Lieutenant R. O. Lloyd R. E. worked out the discharges for 1872 from the Zaloon observations; and native computors have, under the writer's immediate supervision, reduced those for 1873. The Zaloon cross-section varied a good deal from time to time as the observations were in progress, and it was found necessary to change the position in 1873 from that used in 1872. In 1873 the channel, as before mentioned, was transferred from the left bank to the right bank while the measurements were in progress.

Zaloon measurements.

312. The Thapangyo observations were in the first instance taken by Mr. H. J. Richard, C. E. to whom the writer is indebted for much kindly aid at great sacrifice to himself. It would have been desirable to have had the Nawoon measurements made immediately at the entrance of the channels from the Irrawaddy river; but, in the first place, this would have necessitated two sets of observers, one on the Thambyading, the other on the Nawoon; and in the second place, the Irrawaddy water spills over the low bank south of Loodauzoo at comparatively low gauge readings, and this would have escaped past the measuring stations unobserved. It was found requisite therefore to choose the station below the junction of the two entrances, at a point where all the spill from the Irrawaddy has joined the Nawoon. The only suitable place was in a comparatively straight reach of the river at Thapangyo, which has the advantage of being a short distance above the Kyoukyua torrent stream whose elevated channel prevents the free flow of the spill water down the low ground to the west of the station. The calculations for discharge have been mostly made by native computors under the writers direction.

Thapangyo measurements.

313. The three stations were thus determined by natural conditions leaving little choice open. They entailed the disadvantage for purposes of calculation of including a large gathering ground for rainfall between the upper stations of Saiktha and the two lower ones of Zaloon and Thapangyo. These gathering grounds are five in number, and are included under too distinct heads:—those contributing immediately to the Irrawaddy channel to the north of Zaloon; and those which

Disadvantages attending the three stations chosen.

discharge directly into the Nawoon. The former are the Patashin torrent basin and the neighbouring high land, and the area of the river channel included between Saiktha and Zaloon, and bounded by the permanent banks of the river. The others are the Ma-Mya and Okpho torrent basins and Myanoung plain, the rainfall from which, though a portion finds its way at present to the Irrawad dy south of Loodauzoo, is mostly discharged into the Nawoon to the south west of Thambyading.

314. The areas of these gathering grounds are :—

Table 31.

Rainfall gathering grounds between Saiktha and the lower stations.	Irrawaddy tributaries.	Area of river channel ...	305	square miles.
		Basin of Patashin torrent ...	403	„ „
	Nawoon do.	Basin of Mamya torrent ...	105	„ „
		Basin of Okpho torrent ...	215	„ „
		Myanoung plain ...	533	„ „
		Total ...	1,561	square miles.

the contribution of the amount of rainfall from these must be added to the Saiktha discharge to obtain the total volume of the river above the lower stations. Unfortunately, no rainfall was observed nearer than Henzada during the years 1872 and 1873, and this, though it may be somewhat heavier than that at Myanoung to the north, is not so heavy as that nearer to the sea to the west, or in the Arakan Yomas, where the torrent basins lie. We may, however, assume it to be near the average of the whole. That portion of it falling directly on the 305 miles of river surface will of course be added directly to the river volume without change of amount. And in the flood months the ground is so saturated that it absorbs little of the fall; while the moisture of the air prevents much evaporation. It will not be far from the truth therefore if the Henzada fall be taken to represent the whole contribution.

The Henzada rainfall in 1872 & 1873.

315. In 1872 the rainfall recorded at Henzada was for the flood months.

July.	August.	September.	October.	
19·55	14·15	10·00	5·50	inches.
				which give
1,984	1,438	1,015	355	million metre tons (1).

of water to the 1561 square miles intervening between the measuring stations. Of this, that falling on the river is delivered immediately, and the portion falling on the Patashin torrent basin follows in a very short time. The other torrent basins shed their rainfall immediately; but it is received in the plain below, which it helps to inundate and where it is partially stored up with the rainfall on the plain itself, to be delivered slowly in moderate afflux to the Nawoon river. In this manner a portion of the July rainfall, probably one half or 1000 million tons, would reach the river in August, and a similar part of the August's rainfall be delivered in September. It will be sufficient to take half of each month's supply with half of the preceding months, to obtain the addition of volume to the river. The additions would thus be:—

August.	September.	October.	
1,700	1,200	850	million tons of rainfall added to the river.

The 1872 flood discharge in August.

316. On turning to Table 31 it is seen that the river rose from 30·66 feet on the 1st August 1872 at Saiktha to 36·00 by the 31st, the total quantity passing that station in the interval being 93,352 million tons, which the added rainfall brings up to 95,052 millions. The Zaloon guage rose in the same interval of time from about 37 feet to 37·92 feet, while about 86,379 million tons are computed to have passed that station, and during the same time 6,794 million went down the Nawoon past Thapangyo. There is a deficiency between the sum of the last two and that of Saiktha of 159 million tons which the added rainfall of 1,700 million

(1). One inch of rainfall yields a quantity of about 65,000 tons per square mile.

brings up to 1859 millions. As no spill goes over the left bank until the river surface stands higher than the above gauge figure, and the Teadau stream flowing to the Hline takes very little water at 30 feet of the Saiktha gauge, and not much even with the other streams, at 36 feet gauge, the greater part of this surface water must have been reservoired in the 305 square miles (or 791 million square metres) of river channel between Saiktha and Zaloon. If the whole of the upper surface of this channel were free from islands, as is the case for floods above 37 to 39 feet on the gauges, each metre in depth would store 791 million cubic metres; bnt the capacity very much diminishes with the fall of the gauge, as the islands and sandbanks protrude into this space. But when allowance is made for the storage capacity of at least 300 square miles of the Myanoung plain which is inundated during the floods to depths up to 20 feet, sufficient reservoir room is indicated to store up the balance of the 1,859 millions unaccounted for.

The discharges in September and October.

317. From the 31st August the river falls from 36·00 feet at Saiktha to 21·91 feet by the 31st October 1872, the discharge in September being 77,664 million tons, in October 82,494 millions past that place; the added rainfalls being 1,200 and 850 millions respectively. The sum total furnished to the river above the lower measuring stations is thus 162,208 million tons in those two months. During the same time the river fell from 38·00 feet at Zaloon to 30·58 feet; the discharge there being 80,105 millions in September, and 79,799 million tons in October; in the former month showing an excess over the Saiktha contribution, in the latter a deficiency, but on the whole almost on equality, as 159,883 million tons passed Zaloon against 160,158 received at Saiktha. When, however, it is seen that in September 5,512 million tons and in October 5,807 millions passed Thapangyo on the Nawoon during that time, bringing the total discharge at the lower stations for the two months to 171,202 million tons or 8,994 millions above that received at Saiktha an explanation is required of the discrepancy.

Discrepancies in the observed results.

318. In the first place the added rainfall of 2,050 million tons reduces this excess to 6,944 million tons. Secondly, the storage capacity of the channel contained on the 305 square miles of river surface between the height of 36 and 22 feet at Saiktha, and 38 and 30½ feet Zaloon must furnish a considerable amount, which cannot be calculated, as the mass of the islands &c., protruding into this space is not known. Taken at an average depth of 3 metres this space holds 2,373 million metre tons, if quite clear of islands. But probably not more than 2/3rds of it is clear, or say 1,580 million tons were added to the lower discharges from this source. This taken from 6,944 leaves 5,364 million tons still to be accounted for. The 300 square miles of the flooded Myanoung plain is a third source of supply of this excess. It would be quite drained by the fall of the river surface, and if, as is possible, it held the quantity first computed for the free river channel as above or nearly 2,373 million tons, this amount reduces the excess to 3,000 million tons which cannot now be directly accounted for. The quantity would of course be increased by any loss through the creeks of the left bank between Saiktha and Zaloon. Two probable sources of error may be indicated in the above analysis. The rainfall is only taken from the one station of Henzada, which lies in an open paddy plain in the delta with no irregularity of the ground higher than an ant-hill within a radius of 40 miles in any direction. Probably the rainfall on the 700 square miles of the Arakan Yomas is much heavier than at Henzada and would yield a larger volume of water than that computed. Again the Zaloon discharges are probably slightly too high, owing to the fault already mentioned of only a few sub-surface velocities having been taken in the first period of observation, and which are higher in ratio than those at Saiktha, and also than those found at Zaloon in 1873 when the full number of 10 series daily were observed. It was thought better to use the actual figures obtained in 1872 than to substitute ratios borrowed from the second season's observations.

The 1873 rainfall.

319. It is much to be regretted that neither in 1872 nor in 1873 was a complete flood season observed. In the latter year the writer went on furlough, and his successor thought the observations had been long enough continued when the heaviest flood of the year was over in August; and the money provided falling short, he discontinued them. The result given in Table 31 for the three months June to August 1873 are, nevertheless, valuable. They show the operation of the reservoirs during rising flood. The rainfalls of the three months observed

	June.	July.		August.	
were at Henzada	22·55	30·95		7·85	which on the
1,561 square miles, yielded	2,288	3,140	and	796	million tons, of
which we may assume that	1,144	2,714	and	1,968	millions reached

the river in those months.

The 1873 flood discharges in June.

320. The Thapangyo station was not observed in June. The Saiktha gauge rose from 1·645 feet to 29·12 feet in that month, with a volume of water passing of 37,425 million tons. At Zaloon the gauge rose from 8·53 feet to 34·13 feet, while 32,741 million tons passed. There is a deficiency here of 4,684 million tons, which increased by the rainfall of 1,144 million brings the total to 5,828 millions. As June, however, was the first month of the rains, probably little of the rainfall reached the channel during that month, but was employed saturating the ground and filling the plain reservoir so as to discharge in July. The Thapangyo discharge was probably 3,000 million tons in this time. The balance of 2,828 million tons must have been wholly employed in filling the river channel and the reservoir of the lower Myanoung plain.

The discharges in July 1873.

321. In July 1873 we meet a similar difficulty to that found in September 1872. The Saiktha gauge reads 29·00 feet at the begining, 28·50 feet at the end of the month. The Zaloon one varies from 34·25 feet to 35·17 feet. The reservoir action of the channel for the whole month must therefore have been nearly *nil*. Yet the Saiktha discharge was only 68·398 million tons, while the Zaloon one records 70·698 and the Thapangyo one 4,122 million, leaving a total excess at the lower stations of 6,422 million tons in the month. This is lessened by the rainfall, which as taken above added 2,714 million tons, thus reducing the unexplained excess to 3,700 million. We are driven to the unavoidable conclusion that the total rainfall added in July must have been largely in excess of that shown, and that possibly most of June's fall and most of that of July reached the river in the latter month, while the addition from the Arracan hills greatly exceeded that indicated at Henzada. This conclusion appears the more probable, as the August records show a close agreement in the various discharges; while the observations on the river were in more regular operation than in 1873.

The discharges in August 1873.

322. During August 1873 the gauge at Saiktha rose from 28·66 feet to its highest at 34·64 feet, and again fell to 32·66 by the end of the month. At Zaloon the corresponding changes were from 34·83 feet to 37·84 feet, with a fall again to 36·29 by the 31st. The discharge at Saiktha was 86,258 million tons; the added rainfall, as taken above, bringing it to 88,226 millions; but if, as concluded in the last paragraph, the July rainfall mostly reached the river in that month the total volume would be little over 87,000 million tons in August. The discharge at Zaloon of 78,338 million tons, and that at Thapangyo of 6,010 millions total 84,348 millions which are less by from 3,000 to 4,000 million tons than the quantity entering the river. Only a small portion of this could be lost through the left bank, so that the greater part was stored up in the river channel and the Myanoung plains, to be afterwards delivered in September.

323. The effect of completing the Myanoung Embankment will be to shut out the plain behind it entirely from the action of the Irrawaddy water, but it will at the same time cut off the connection between the rainfall upon it and the supply to the larger river. So long as the Thambyading river is left open no result of importance can follow the closing of the remainder of the openings, as

the quantity of water lost through these or draining to the Nawoon from the 853 miles of land behind the Myanoung embankment is a small part of the total quantities recorded as passing down the Nawoon river at Thapangyo, never, on the average, amounting to one fourth of the total, whether derived from the local rainfall, or from the spill over the bank from Loodauzoo to Thambyading. It would thus be a more serious matter to shut this river entirely, and so to include the quantity now passing off by the Nawoon, and amounting in flood months to between 4,000 and 5,000 million tons, in the Irrawaddy above Zaloon. The effect of doing this may be seen in the variations of the gauges and discharges respectively at Saiktha and at Zaloon.

Variation in height and discharge of flood at Saiktha and at Zaloon.

324. On taking the months of August in 1872 and in 1873, and comparing their variation of gauge reading and discharge at Saiktha and Zaloon some prominent facts are observable. In August 1872 the gauge varies from 30·33 feet to 36·00, or in all by 5·67 feet while at Zaloon the variation is only from the lowest point 36·04 feet to 38·17 feet, early in September, the crest of the wave taking some days to travel the 100 miles. The variation of height is only 2·13 feet at Zaloon against 5·67 feet at Saiktha. The lowest discharge at Saiktha was 2,436 million tons on the 2nd August, the highest 3,528 on the 31st. The corresponding discharges at Zaloon are 2,685 millions on the 7th August, and 3,020 on the 4th September. The extreme variation being 1,092 million tons in the one case; and 335 million in the other. In August 1873 there was a variation of gauge height of 6 feet and of discharge of 928 million tons, while at Zaloon the variations were 3·54 feet in height and about 500 million tons in discharge, a remarkable fall taking place at Zaloon by the 23rd August not observable at Saiktha, probably due to the deficient supply of rainfall. In this latter month the gauges read one or two feet lower than in August 1872. The inference from these facts is that at a gauge reading from 30 to 36 feet a daily volume amounting to 1,000 million tons at Saiktha, only raises the Zaloon gauge about 2 feet, and the discharge is moderated to one of little over 300 million tons per day, through being distributed over several days. With a Saiktha gauge from 29 to 34½ feet a daily wave volume of 900 millions is reduced to one of 500 millions at Zaloon with a rise of 3½ feet. The flood waves of 1871, 1875 and 1877 show that the variations at the higher gauge readings are still less proportionally for larger volumes of water than at the low gauges.

Probable elevation of surface in ordinary flood to closing both sides of river.

325. It is probable that if the whole of the 6,794 million tons discharged past Thapangyo had been shut in to the Irrawaddy in August 1872, the amount would have raised the river surface at Zaloon by about 1½ feet. The highest daily rate is 255 million tons. We have seen that an increased discharged of 335 millions only raised the river surface 2·13 feet from 36·04 feet on the gauge. At higher stands of the river the raising of the surface is less; but a simple proportion proves that the 255 million tons would raise the river little more than 1½ feet at 36 feet gauge. By working out the respective rates of raising at the different river gauges which the complete closing in of the channel by enbanking would entail, and by following out the clues offered by the passage of the observed flood waves down the channel in the modifications of form of crest, of secular surface and of rate of discharge, and reasoning from these to the greatest contemplated floods it will finally be possible to assign the probable heights to which the embankment works must be raised to ensure success to the proposed works on both banks.

Insufficiency of mathematical computation of result.

326. But to the practician who has been in prolonged contact with the actual problem the question presents itself in a different form to that in which it would be considered by the analyst who considers it as a mere exercise of intellectual skill. In the latter case all the most important modifying conditions are more or less abstracted, and the crude outlines of the facts alone can be grasped by the mathematical formula; which, at present, are neither susceptible

to completely continuous scientific treatment, nor merit higher confidence than must be accorded to them as purely speculative results of high philosophical research. As a discipline of the mind, and as affording suggestions to the proper ends of the enquiry, they are invaluable; but they can neither define nor comprehend the complex conditions of practice, nor prescribe rules likely to subserve any immediately useful purpose.

Necessity of a complete critical study of all the details.

327. The Engineer, on the contrary, who is responsible for the safety in design and for the economical execution of the works has necessarily to pay the utmost attention not only to the general rules which experience elsewhere has laid down, but to the whole of the peculiar and modifying conditions to be met with in the particular case before him. A complete discussion of all these conditions, most of which have been enumerated or alluded to in the preceding paragraphs, must thus go hand in hand with the consideration of each rule, and must precede any attempt to give in actual figures the definitive results of the calculation. It would be well if a new attempt could be made to procure the necessary data which have been shown now to be wanting by the foregoing examination of the materials. The value of the present data would be enhanced much by discharge observations carried out simultaneously for an entire flood season, at four or five different points of the rivers course, supplemented by more extended rainfall observations over the areas concerned. The changes in progress in the river could be further detailed and described. Possibly completer data may soon be available for the hydrology of the Irrawaddy valley; and the steps now being taken to decide the disputed question of the Irrawaddy sources be crowned with success. No efforts should be spared to secure any information likely to give precision to the results of calculation; and, in the delta itself, the staff requisite for keeping the present embankment works in good order can be usefully employed in continuing the observations already made.

A consideration of the Nawoon results of high utility.

328. In the meantime an account of the temporary failures and subsequent success of the attempts to embank the Nawoon river, practically encasing it completely, will aid the solution of the problem under consideration in the Irrawaddy. The succeeding part of this Report recounts progress made in this direction.

Appendix I.

Comparison of Measured and Scaled Discharges at **Saiktha** *for the years* 1872-1873, *in Metre-Tons per day.*

Year.	Date.	Gauge.	Measured Discharge.	Scaled Discharge.	Difference.	Per Cent.
August 1872.	1	30·66	2,593,000,000	2,524,681,720	− 68,318,280	− 2·63
	2	30·33	2,436,400,000	2,483,318,860	+ 46,918,860	+ 1·92
	3	30·41	2,602,400,000	2,615,016,580	+ 12,616,580	+ ·50
	4	30·33	...	2,483,318,860	...	...
	5	31·83	2,894,000,000	2,801,721,980	− 92,278,020	− 3·17
	6	32·83	3,028,000,000	2,933,051,260	− 94,948,740	− 3·13
	7	33·41	3,117,100,000	3,031,185,120	− 85,914,880	− 2·75
	8	34·33	3,165,200,000	3,177,034,140	+ 11,834,140	+ ·37
	9	34·58	3,210,200,000	3,217,873,640	+ 17,673,640	+ ·56
	10	34·75	3,240,400,000	3,245,644,500	+ 5,244,500	+ ·15
	11	35·00	...	3,290,153,000	...	...
	12	35·00	...	3,290,153,000	...	...
	13	34·83	3,081,700,000	3,127,194,260	+ 45,494,260	+ 1·46
	14	34·41	3,009,200,000	3,059,901,020	+ 50,701,020	+ 1·69
	15	33·75	2,923,500,000	2,954,313,000	+ 30,813,000	+ 1·06
	16	33·25	2,871,900,000	2,880,113,000	+ 8,213,000	+ ·28
	17	33·00	2,704,700,000	2,843,013,000	+ 138,313,000	+ 5·10
	18	32·83	...	2,817,160,000	...	...
	19	32·75	2,658,400,000	2,806,048,000	+ 147,648,000	+ 5·56
	20	32·91	2,800,500,000	2,954,317,020	+ 153,817,020	+ 5·50
	21	33·16	2,938,200,000	2,993,477,120	+ 55,277,120	+ 1·87
	22	33·41	...	3,031,185,120	...	...
	23	33·75	2,978,200,000	3,082,468,000	+ 104,268,000	+ 3·48
	24	34·16	...	3,149,263,280	...	...
	25	35·00	...	3,290,153,000	...	...
	26	35·16	...	3,318,748,200	...	...
	27	35·41	...	3,363,428,200	...	...
	28	35·66	...	3,408,108,200	...	...
	29	35·83	3,391,200,000	3,438,490,600	+ 47,290,600	+ 1·38
	30	36·00	3,509,300,000	3,473,400,000	− 35,900,000	− 1·02
	31	36·00	3,527,800,000	3,473,400,000	− 54,400,000	− 1·53
September 1872.	1	35·83	...	3,302,843,760	...	...
	2	35·50	3,468,200,000	3,245,202,000	− 222,998,000	− 6·43
	3	35·08	3,311,100,000	3,171,839,760	− 139,260,240	− 4·19
	4	34·25	...	3,034,265,500	...	...
	5	33·50	2,945,000,000	2,917,213,000	− 27,787,000	− ·95
	6	32·83	2,912,500,000	2,817,160,000	− 95,340,000	− 3·26
	7	32·33	2,855,100,000	2,747,710,000	− 107,390,000	− 3·74
	8	32·08	...	2,712,985,000	...	...
	9	31·83	2,686,900,000	2,677,708,920	− 9,191,080	− ·34
	10	31·58	2,669,600,000	2,644,877,920	− 24,722,080	− ·93
	11	31·50	2,639,600,000	2,634,372,000	− 5,228,000	− ·19
	12	31·75	2,591,600,000	2,791,081,500	+ 109,481,500	+ 4·20
	13	31·66	2,583,000,000	2,655,383,840	+ 72,383,840	+ 2·78
	14	31·41	...	2,622,552,840	...	...
	15	31·08	...	2,579,215,920	...	...
	16	31·00	2,572,300,000	2,568,710,000	− 5,590,000	− ·11
	17	30·66	2,501,700,000	2,524,681,720	+ 22,981,720	+ ·92
	18	30·16	...	2,462,010,720	...	...
	19	29·58	2,290,700,000	2,390,192,760	+ 9,492,760	+ ·39
	20	28·66	2,254,700,000	2,279,588,200	+ 24,888,200	+ 1·10
	21	27·75	2,181,400,000	2,173,395,000	− 8,005,000	− ·36
	22	26·58	...	2,041,286,000	...	...
	23	25·33	1,952,300,000	1,905,870,000	− 46,430,000	− 2·35
	24	25·50	1,950,900,000	2,035,408,000	+ 84,508,000	+ 4·30
	25	26·50	2,143,400,000	2,147,131,000	+ 3,731,000	+ ·18
	26	28·00	...	2,320,225,000	...	...
	27	28·83	2,325,500,000	2,418,601,580	+ 93,101,580	+ 4·00
	28	29·75	2,362,400,000	2,531,309,500	+ 168,909,500	+ 7·15
	29	30·50	...	2,626,441,000	...	...
	30	31·66	2,783,200,000	2,779,110,960	− 4,089,040	− ·14

Appendix I.—Continued

Comparison of Measured and Scaled Discharges at **Saiktha,** *for the years* 1872-1873.

Year.	Date.	Gauge.	Measured Discharge.	Scaled Discharge.	Difference.	Per Cent.
October 1872.	1	32·25	2,921,100,000	2,861,374,500	− 59,725,500	− ·20
	2	32·66	2,937,700,000	2,919,111,520	− 18,588,480	− ·61
	3	32·91	3,000,100,000	2,954,317,020	− 45,782,980	− 1·53
	4	33·00	3,053,500,000	2,969,344,000	− 84,156,000	− 2·75
	5	33·41	3,038,100,000	3,031,185,120	− 6,914,880	− ·23
	6	33·00	...	2,843,031,000	...	...
	7	32,83	2,871,900,000	2,817,160,000	− 54,740,000	− 1·91
	8	32·75	2,863,100,000	2,806,048,000	− 57,052,000	− 1·99
	9	32·58	2,888,100,000	2,782,435,000	− 105,665,000	− 3·67
	10	32·41	2,852,300,000	2,758,822,000	− 93,478,000	− 3·26
	11	32·16	...	2,724,097,000	...	...
	12	31·75	2,698,500,000	2,667,203,000	− 31,297,000	− 1·14
	13	31,41	...	2,622,552,840	...	...
	14	31·16	2,632,900,000	2,589,721,840	− 43,178,160	− 1·63
	15	31·08	2,607,200,000	2,579,215,920	− 27,984,080	− 1·07
	16	31·16	2,632,400,000	2,712,607,960	+ 80,207,960	+ 3·03
	17	31·58	...	2,768,470,480	...	...
	18	32·25	2,795,100,000	2,861,374,500	+ 66,274,500	+ 2·36
	19	32·75	2,944,600,000	2,931,785,500	− 12,814,500	− ·44
	20	33·00	...	2,969,344,000	...	...
	21	33·25	3,145,600,000	3,007,052,000	− 138,548,000	− 4·38
	22	33·00	2,871,700,000	2,843,013,000	− 28,687,000	− 1·01
	23	32·41	2,749,100,000	2,758,822,000	+ 9,722,000	+ ·36
	24	31·58	2,665,200,000	2,644,877,920	− 20,322,080	− ·75
	25	31·58	2,598,400,000	2,644,877,920	+ 46,477,920	+ 1·77
	26	29·41	2,350,700,000	2,369,678,520	+ 18,978,520	+ ·80
	27	28·33	...	2,241,070,600	...	...
	28	26·58	1,954,000,000	2,041,286,000	+ 87,286,000	+ 4·45
	29	25·16	1,843,000,000	1,886,670,960	+ 43,670,960	+ 2·38
	30	23·91	1,737,700,000	1,755,030,540	+ 17,330,540	+ ·97
	31	21·91	1,547,200,000	1,555,797,320	+ 8,597,320	+ ·51
November 1872.	1	22·33	1,632,500,000	1,700,740,040	+ 68,240,040	+ 4·04
	2	22·08	1,623,500,000	1,572,883,920	− 50,616,080	− 3·14
	3	22·08	...	1,572,883,920	...	...
	4	24·81	1,852,300,000	1,959,663,040	+ 107,363,040	+ 5·77
	5	24·50	1,814,000,000	1,816,817,000	+ 2,817,000	+ ·16
	6	23·91	1,788,900,000	1,755,030,540	− 33,869,460	− 1·90
	7	23·16	1,720,300,000	1,679,510,040	− 40,789,960	− 2·38
	8	22·08	1,536,200,000	1,572,883,920	+ 36,683,920	+ 2·40
	9	20·91	1,446,600,000	1,460,938,440	+ 14,338,440	+ ·96
	10	19·25	...	1,311,159,000	...	...
	11	18·58	1,262,200,000	1,252,730,200	− 9,469,800	− ·71
	12	17·75	1,182,800,000	1,182,312,500	− 587,500	− ·05
	13	16·25	...	1,061,391,500	...	...
	14	15·75	1,097,300,000	1,022,141,000	− 75,159,000	− 6·83
	15	15·08	952,370,000	971,688,560	+ 19,298,560	+ 1·90
	16	14·33	902,940,000	916,500,123	+ 13,560,120	+ 1·44
	17	13·91	...	885,683,720	..	...
	18	13·33	836,280,000	845,668,360	+ 9,388,360	+ 1·07
	19	12·91	795,940,000	816,184,380	+ 20,244,380	+ 2·51
	20	12·50	771,920,000	789,199,000	+ 17,279,000	+ 2 20
	21	12·08	745,710,000	761,555,440	+ 15,845,440	+ 2·14
	22	11·75	714,910,000	739,836,000	+ 24,926,000	+ 3·49
	23	11·41	709,630,000	718,535,680	+ 8,905,680	+ 1·26
	24	11·16	...	702,873,680	...	...
	25	10·79	661,410,000	679,568,620	+ 18,158,620	+ 2·72
	26	10·50	640,100,000	662,320,000	+ 22,220,000	+ 3·43
	27	10·25	632,020,000	647,450,500	+ 15,430,500	+ 2·37
	28	10·00	618,960,000	632,581,000	+ 13,621,000	+ 2·26
	29	9·75	625,900,000	617,711,500	− 8,188,500	− 1·27
	30	9·56	...	607,013,360	...	...

Appendix I.—continued.

Comparison of Measured and Scaled Discharges at **Saiktha,** *for the years* 1872-1873.

Year.	Date.	Gauge.	Measured Discharge.	Scaled Discharge.	Difference.	Per Cent.
December 1872.	1	9·41	...	598,567,460	...	...
	2	9·16	...	584,490,960	...	..
	3	9·00	555,180,000	575,482,000	+20,302,000	+3·60
	4	8·75	540,930,000	561,406,000	+20,476,000	+3·69
	5	8·58	553,030,000	552,372,880	− 657,120	− ·11
	6	8·41	547,030,000	543,339,760	− 3,690,240	− ·67
	7	8·20	543,370,000	532,181,200	−11,188,800	−2·02
	8	8·00	...	521,554,000	...	...
	9	7·87	524,100,000	514,339,880	− 9,760,120	−1·90
	10	7·75	515,900,000	508,301,000	− 7,599,000	−1·36
	11	7·58	507,460,000	499,745,920	− 7,714,080	−1·58
	12	7·45	487,120,000	493,203,000	+ 6,083,000	+1·24
	13	7·33	487,000,000	487,164,920	+ 164,920	+ ·04
	14	7·16	...	478,609,840	...	...
	15	7·00	468,650,000	470,558,000	+ 1,908,000	+ ·43
	16	6·83	454,580,000	461,841,500	+ 7,261,500	+1·54
	17	6·66	457,510,000	453,690,000	+ 3,820,000	− ·87
	18	6·45	430,560,000	443,620,500	+13,060,500	+3·02
	19	6·33	425,990,000	437,866,500	+11,876,500	+2·82
	20	6·25	...	434,030,500	...	...
	21	6·00	422,530,000	422,043,000	− 487,000	− ·12
	22	5·08	...	379,265,360	...	...
	23	5·79	420,430,000	432,278,580	+11,848,580	+2·86
	24	5·58	407,430,000	402,261,360	− 5,168,640	−1·23
	25	5·41	...	394,442,720	...	...
	26	5·29	403,990,000	388,923,680	−15,066,320	−3·71
	27	5·25	...	387,084,000	...	...
	28	5·08	392,170,000	379,265,360	−12,904,640	−3·32
	29	5·00	...	375,586,000	...	...
	30	4·83	386,150,000	367,661,980	−18,488,020	−4·66
	31	4·75	363,690,000	364,109,500	+ 419,500	+ ·11
January 1873.	1	4·66	...	360,112,960	...	...
	2	4·54	359,590,000	354,784,240	− 4,805,760	−1·35
	3	4·45	360,560,000	350,787,700	− 9,772,300	−2·50
	4	4·33	351,460,000	345,458,980	− 6,001,020	−1·71
	5	4·25	...	341,906,500	...	...
	6	4·16	332,140,000	337,909,960	+ 5,769,960	+1·51
	7	4·08	329,860,000	334,357,480	+ 4,497,480	+1·21
	8	4·00	...	330,805,000	...	...
	9	3·91	328,230,000	326,627,140	− 1,602,860	− ·31
	10	3·81	...	322,311,740	...	...
	11	3·75	...	319,722,500	...	...
	12	3·62	320,000,000	314,112,480	− 5,887,520	−1·57
	13	3·50	307,020,000	308,934,000	+ 1,914,000	+ ·65
	14	3·45	314,940,000	306,776,300	− 8,163,700	−2·54
	15	3·41	327,680,000	305,050,140	−22,629,860	−6·73
	16	3·37	315,740,000	303,323,980	+12,416,020	−3·81
	17	3·33	297,030,000	301,597,820	+ 4,567,820	+1·35
	18	3·29	296,420,000	299,871,660	+ 3,451,660	+1·01
	19	3·25	...	298,145,500	...	...
	20	3·21	294,790,000	296,419,340	+ 1,629,340	+ ·34
	21	3·16	294,660,000	294,261,640	− 398,360	− ·10
	22	3·12	292,960,000	292,535,489	− 424,520	− ·14
	23	3·00	...	287,357,000	...	...
	24	2·91	287,440,000	283,336,360	− 4,103,640	−1·39
	25	2·83	287,260,000	279,960,680	− 7,299,320	−2·44
	26	2·75	...	276,585,000	...	...
	27	2·95	291,420,000	294,332,300	+ 2,912,300	+ ·68
	28	3·04	299,470,000	298,765,120	− 704,880	− ·23
	29	3·08	308,800,000	300,604,240	− 8,195,760	−2·60
	30	3·04	298,010,000	289,083,160	− 8 926,840	−2·70
	31	2·95	287,270,000	285,024,200	− 2,245,800	− ·70

Appendix I.—continued.

Comparison of Measured and Scaled Discharges at **Saiktha,** *for the years* 1872-1873.

Year.	Date.	Gauge.	Measured Discharge.	Scaled Discharge.	Difference.	Per Cent.
February 1873.	1	2·87	286,090,000	281,648,520	− 4,441,480	−1·40
	2	2·70	...	274,475,200	...	...
	3	2·58	277,740,000	269,411,680	− 8,328,320	−2·90
	4	2·47	276,730,000	264,770,120	−11,959,880	−4·33
	5	2·39	268,280,000	261,394,440	− 6,885,560	−2·24
	6		...	258,018,760	...	...
	7	2·22	257,810,000	254,221,120	− 3,588,880	−1·17
	8	2·16	258,520,000	251,689,360	− 6,830,640	−2·32
	9	2·08	...	248,313,680	...	...
	10	1·95	...	242,701,500	...	...
	11	1·95	231,080,000	242,701,500	+11,621,500	+4·76
	12	1·91	...	241,041,900	...	...
	13	1·90	...	240,627,000	...	...
	14	1·98	226,970,000	240,212,100	+13,242,100	+5·75
	15	1·79	223,500,000	236,063,100	+12,563,100	+5·38
	16	1·70	...	232,329,000	...	...
	17	1·60	223,430,000	228,180,000	+ 4,750,000	+1·80
	18	1·58	228,860,000	227,350,200	− 1,509,800	+ ·43
	19	1·52	226,700,000	224,860,800	− 1,839,200	+ ·44
	20	1. 43	227,800,000	221,126,700	− 6,673,300	+2·64
	21	1·35	227,240,000	217,807,500	− 9,432,500	+3·96
	22	1·29	226,320,000	215,318,100	−11,001,900	+4·42
	23	1·20	...	211,584,000	...	...
	24	1·125	223,122,000	219,552,000	− 3,570,000	+1·34
	25	1·125	215,557,000	219,552,000	+ 3,995,000	+1·40
	26	1·145	...	228,184,000	...	...
	27	1·08	209,533,000	206,605,200	− 2,927,800	+ ·96
	28	1·02	...	204,115,800	...	...
March 1873.	1	·97	197,734,000	181,444,940	−16,289,060	−8·12
	2	·97	198,248,000	181,444,940	−16,803,060	−8·08
	3	·95	193,183,000	180,624,900	−12,558,100	−6·22
	4	·91	199,818,000	178,984,820	−20,833,180	−1·00
	5	1·00	205,944,000	208,762,000	+ 2,818,000	+ ·97
	6	1·125	209,746,000	213,941,200	+ 4,195,200	+1·91
	7	1·20	214,957,000	217,394,000	+ 2,437,000	+ ·93
	8	1·25	215,010,000	219,552,000	+ 4,542,000	+1·86
	9	1·312	225,760,000	222,141,600	− 3,618,400	−1·33
	10	1·375	236,642,000	224,731,200	−11,910,800	−5·08
	11	1·666	246,386,000	237,679,200	− 8,706,800	−3·25
	12	1·729	...	240,268,800	...	...
	13	1·812	249,354,000	243,721,600	− 5,632,400	−2·01
	14	1·58	226,607,000	227,350,200	+ 743,200	+ ·31
	15	1·375	218,621,000	218,637,300	+ 16,300	+ ·01
	16	1·229	...	212,828,700	...	...
	17	1·00	...	203,286,000	...	...
	18	·979	...	181,854,960	...	...
	19	·875	...	177,344,740	...	...
	20	1·062	...	211,351,600	...	...
	21	1·29	235,922,000	221,278,400	−14,643,600	+5·95
	22	1·375	232,504,000	224,731,200	− 7,772,800	+3·02
	23	1·25	216,578,000	213,658,500	− 2,919,500	+ ·92
	24	1·125	208,244,000	208,264,800	+ 20,800	+ 01
	25	1·125	205,829,000	208,264,800	+ 2,435,800	+ ·97
	26	1·25	215,827,000	219,552,000	+ 3,725,000	+1·39
	27	1·27	217,410,000	220,415,200	+ 3,005,200	+1·38
	28	1·166	...	210,339,300	...	...
	29	1·00	...	203,286,000	...	...
	30	·91	...	178,984,120	...	...
	31	·81	...	174,884,620	...	...

Appendix I.—continued.

Comparison of Measured and Scaled Discharges at **Saiktha,** *for the years* 1872-73.

Year.	Date.	Gauge.	Measured Discharge.	Scaled Discharge.	Difference.	Per Cent.
April 1873.	1	·729	...	171,604,460	...	...
	2	· 75	...	176,827,000	...	...
	3	1· 02	...	209,625,200	...	...
	4	1· 75	...	241,132,000	...	...
	5	2·625	258,631,000	279,695,480	+21,064,480	+ 8·14
	6	2·875	275,135,000	290,783,980	+15,648,980	+ 5·46
	7	2· 75	275,184,000	276,585,000	+ 1,401,000	+ ·37
	8	2· 50	274,586,000	266,036,000	- 8,550,000	- 2·92
	9	2·208	251,131,000	253,799,160	+ 2,668,160	+ ·80
	10	1· 97	242,763,000	243,531,300	+ 768,300	+ ·29
	11	1· 75	...	234,403,500	...	...
	12	1· 58	230,261,000	227.350,200	- 2,910,800	- 1·30
	13	1·416	223,450,000	220,711,800	- 2,738,200	- ·90
	14	1· 29	218,218,000	215,318,100	- 2,889,900	- ·92
	15	1· 20	214,480,000	211,584,000	- 2,896,000	- ·93
	16	1·166	213,068,000	210,339,300	- 2,728,700	- ·94
	17	1·145	212,490,000	209,094,600	- 3,395,400	- 1·42
	18	1·145	213,961,000	209,094,600	- 4,866,400	- 1·88
	19	1·166	216,033,000	216,099,200	+ 66,200	+ ·03
	20	1·104	212,654,000	247,435,000	- 5,219,000	- 2·36
	21	1· 02	210,592,000	204,115,800	- 6,476,200	- 2·90
	22	· 91	205,893,000	178,984,820	-26,908,180	-13·17
	23	· 79	199,011,000	174,064,580	-24,946,420	-12·56
	24	· 76	197,281,000	172,834,520	-24,456,480	-12·18
	25	· 81	203,351,000	179,366,920	-23,984,080	-11·82
	26	·979	209,141,000	186,563,360	-22,577,640	-10·52
	27	...	...	217,825,600	...	...
	28	1· 45	224,500,000	228,184,000	+ 3,684,000	+ 1·34
	29	1·625	234,291,000	235,521,210	+ 1,230,210	+ ·43
	30	1·875	...	246,311,200	...	...
May 1873.	1	2· 04	256,154,000	253,970,160	- 2,183,840	- ·78
	2	2· 58	270,900,000	267,921,320	- 2,978,680	- ·74
	3	3· 21	307,154,000	306,581,380	- 592,620	- ·19
	4	3· 33	...	312,098,740	...	...
	5	3· 46	...	318,075,880	...	...
	6	3· 58	312,564,000	323,593,240	+11,029,240	+ 3·52
	7	3· 56	319,660,000	311,523.240	- 8,136,760	- 2·51
	8	3· 50	318,640,000	308,934,000	- 9,706,000	- 2·83
	9	3· 33	303,497,000	301,597,820	- 1.899,180	- ·33
	10	3· 25	302,511,000	298,145,500	- 4,365,500	- 1·34
	11	3· 15	...	293,830,100	...	...
	12	3· 06	283,554,000	289,946,240	+ 6,392,240	+ 2·12
	13	3· 17	289,514,000	304,742,260	+15,228,260	+ 5·19
	14	3· 41	305,970,000	315,776,980	+ 2,806,980	+ 2·95
	15	3· 58	312,693,000	323,593,240	+10,900,240	+ 3·52
	16	3· 54	302,960,000	310,660,160	+ 7,700,160	+ 2·32
	17	3· 13	...	292,535,480	...	...
	18	2· 90	...	281,648,520	...	...
	19	2· 68	...	273,209,320	...	...
	20	2· 45	259,613,000	263,926,200	+ 4,313,200	+ 1·55
	21	2· 29	247,700,000	257,174,840	+ 9,474.840	+ 3·64
	22	2· 15	255,797,000	250,845,440	+ 4,951,560	- 1·57
	23	2· 17	255,589,000	259,736,180	+ 4,147,180	+ 1·57
	24	2· 33	257,947,000	266,832,820	+ 8,885,820	+ 3·11
	25	2· 41	...	270,381,140	...	...
	26	2· 16	...	251,689,360	...	...
	27	1· 91	250,258,000	241,041,900	- 9,216,100	- 3·60
	28	1: 66	245,928,000	230,669,400	-15,258,600	- 6·12
	29	1· 50	231,286,000	224,031,000	- 7,255,000	- 3·03
	30	1· 38	212,965,000	218,637,300	- 5,672,300	+ 2·36
	31	1· 73	...	240,268,800	...	...

Appendix I.—continued.

Comparison of Measured and Scaled Discharges at **Saiktha,** *for the year* 1872-73.

Year.	Date.	Gauge.	Measured Discharge.	Scaled Discharge.	Difference.	Per Cent.
June 1873.	1	2·08	...	255,744,320	...	...
	2	2·42	268,370,000	270,824,680	+ 2,454,680	+ ·74
	3	2·00	277,180,000	244,938,000	+ 32,242,000	+ 1·55
	4	1·67	245,470,000	231,084,300	+ 14,385,700	+ 5·75
	5	1·65	228,550,000	229,839,600	+ 1,289,600	+ ·43
	6	1·83	242,730,000	244,584,800	+ 1,854,800	+ ·41
	7	2·40	279,230,000	269,494,060	- 9,735,940	- 3·22
	8	3·92	...	339,225,760	...	...
	9	5·33	412,750,000	408,909,660	- 3,841,660	- ·72
	10	6·42	477,590,000	466,250,960	- 11,339,040	- 2·30
	11	8·75	595,510,000	600,267,500	+ 4,757,500	+ ·67
	12	11·25	744,520,000	762,501,000	+ 17,981,000	+ 2·28
	13	12·58	888,760,000	855,926,680	- 32,833,320	- 1·80
	14	14·33	987,240,000	987,134,920	- 1,05,080	- ·01
	15	15·75	1,063,720,000	1,099,729,000	+ 36,009,000	+ 3·38
	16	16·79	1,183,870,000	1,186,147,260	+ 2,277,260	+ ·17
	17	18·25	1,269,740,000	1,313,342,500	+ 43,602,500	+ 3·31
	18	19·58	1,432,490,000	1,434,104,160	+ 1,614,160	+ ·07
	19	21·33	1,587,130,000	1,601,271,100	+ 14,141,100	+ ·88
	20	23·42	...	1,812,478,840	...	...
	21	24·71	2,001,690,000	1,949,004,640	- 52,685,360	- 2·59
	22	25·92	2,166,980,000	2,081,406,400	- 85,573,600	- 3·92
	23	26·58	2,222,990,000	2,156,127,640	- 66,862,360	- 2·98
	24	27·04	2,262,050,000	2,208,710,840	- 53,339,160	- 2·34
	25	27·33	...	2,242,175,680	...	...
	26	27·75	...	2,290,642,000	...	...
	27	28·17	...	2,340,374,420	...	...
	28	28·46	2,346,190,000	2,374,746,960	+ 28,556,960	+ 1·20
	29	29·08	...	2,449,410,040	...	...
	30	29·13	2,497,720,000	2,454,299,560	- 43,420,440	- 1·72
July 1873.	1	29·00	2,409,430,000	2,320,203,000	- 89,227,000	- 3·06
	2	28·58	2,324,420,000	2,270,250,600	- 54,169,400	- 2·32
	3	28·00	2,228,730,000	2,202,553,000	- 26,177,000	- 1·12
	4	27·25	...	2,117,705,000	...	...
	5	26·67	2,000,620,000	2,051,204,000	+ 50,584,000	+ 2·50
	6	25·58	...	1,931,644,480	...	...
	7	25·17	...	1,887,741,520	...	...
	8	24·25	1,922,500,000	1,790,851,000	- 131,649,000	- 6·71
	9	23·50	...	1,713,746,000	...	...
	10	22·92	1,674,280,000	1,654,804,080	- 19,475,920	- 1·17
	11	22·25	1,656,460,000	1,589,463,000	- 66,997,000	- 3·98
	12	22·13	1,712,550,000	1,576,784,880	- 135,765,120	- 2·04
	13	23·75	...	1,846,684,000	...	...
	14	24·54	1,974,710,000	1,930,885,360	- 43,824,640	- 2·17
	15	25·71	2,145,280,000	2,058,407,200	- 86,872,800	- 4·00
	16	27·21	2,258,060,000	2,228,328,160	- 29,731,840	- 2·38
	17	28·42	2,382,590,000	2,370,005,920	- 12,584,080	- ·54
	18	29·75	...	2,531,309,500	...	...
	19	30·25	2,575,540,000	2,594,706,500	+ 19,166,500	+ ·74
	20	31·00	...	2,691,327,000	...	...
	21	31·17	2,643,300,000	2,713,938,020	+ 70,638,020	+ 2·63
	22	31·25	2,704,330,000	2,724,578,500	+ 20,248,500	+ ·73
	23	31·00	2,559,060,000	2,568,710,000	+ 9,650,000	+ ·34
	24	30·67	...	2,525,935,140	...	·65
	25	30·40	2,430,430,000	2,446,969,680	+ 16,539,680	+ ·65
	26	28·75	2,231,300,000	2,290,093,000	+ 58,793,000	+ 2·60
	27	28·50	...	2,260,913,000	...	...
	28	28·25	...	2,231,733,000	...	...
	29	28·50	2,220,070,000	2,379,488,000	+ 159,418,000	+ 7·16
	30	29·17	2,307,070,000	2,460,411,460	+ 153,341.460	+ 6·63
	31	28·50	2,289,580,000	2,260,913,000	- 28,667,000	- 1·22

Appendix I.—concluded.

Camparison of Measured and Scaled Discharges at **Saiktha,** *for the years* 1872-73.

Year.	Date.	Gauges.	Measured Discharge.	Scaled Discharge.	Difference.	Per Cent.
August 1873.	1	28·67	2,306,670,000	2,399,637,420	+ 92,967,420	+ 3·99
	2	29·37	2,440,020,000	2,484,859,060	+ 44,839,060	+ 1·80
	3	30·60	...	2,641,673,560	...	...
	4	31·25	2,596,170,000	2,724,578,500	+128,408,500	+ 4·93
	5	32·33	...	2,872,640,260	...	...
	6	33·08	...	2,981,410,560	...	...
	7	33·75	3,030,520,000	3,082,468,000	+ 51,948,000	+ 1·71
	8	34·17	3,097,930,000	3,150,896,860	+ 52,966,860	+ 1·71
	9	34·42	3,205,850,000	3,191,736,360	- 14,113,640	- ·44
	10	34·64	...	3,227,675,120	...	...
	11	34·50	3,216,400,000	3,074,321,000	-142,079,000	- 4·41
	12	34·125	...	3,013,436,640	...	...
	13	33·37	...	2,897,921,000	...	...
	14	32·58	2,866,260,000	2,782,435,000	- 83,825,000	- 2·90
	15	31·87	2,754,650,000	2,682,961,880	- 71,688,120	- 2·57
	16	31·17	9,633,610,000	2,591,035,080	- 42,574,920	- 1·60
	17	30·42	...	2,494,599,640	...	...
	18	30·08	2,500,510,000	2,451,983,360	- 48,526,640	- 1·92
	19	29·58	...	2,390,192,760	...	...
	20	29·17	2,389,640,000	2,340,717,240	- 48,922,760	- 2·00
	21	29·00	2.419,570,000	2,320,203,000	- 99,367,000	- 4·09
	22	29·00	2,451,900,000	2,320,203,000	-131,697,000	- 5·30
	23	29·67	2,619,520,000	2,521,530,460	- 97,989,540	- 3·70
	24	30·67	...	2,648,020,460	...	...
	25	30·92	...	2,679,754,960	...	...
	26	31·33	2,783,570,000	2,735,218,900	- 48,351,020	- 1·72
	27	31·83	2,813,600,000	2,801,721,980	- 11,878,020	- ·39
	28	32·25	2,875,100,000	2,861,374,500	- 13,725,500	- ·45
	29	32·48	3,029,040,000	2,893,763,560	-135,276,440	- 4·48
	30	32·67	3,074,420,000	2,920,519,740	-153,900,260	- 4·97
	31	32·67	...	2,920,519,740	...	...

Appendix II.

Discharge Scale for **Saiktha,** *for the years* 1872-73.

Gauge Readings.	River Rising.		River Falling.	
	Discharge for each guage reading cubic metres (tons) per diem.	Differences of discharges.	Discharges for each gauge reading in cubic metres (tons) per diem.	Differences of discharges.
...	41,349,000		40,417,000	
- 2·5	62,038,000	20,689,000	60,635,000	20,218,000
- 2·	82,753,000	20,715,000	80,866,000	20,231,000
- 1·5	103,509,000	20,756,000	101,123,000	20,257,000
- 1·0	124,325,000	20,816,000	121,416,000	20,293,000
- 0·5	145,227,000	20,902,000	141,761,000	20,345,000
0	166,244,000	21,017,000	162,174,000	20,413,000
0·5	187,410,000	21,166,000	182,675,000	20,501,000
1·	208,762,000	21,352,000	203,286,000	20,611,000
1·5	230,342,300	21,580,000	224,031,000	20,745,000
2·	252,196,000	21,854,000	244,938,000	20,907,000
2·5	274,373,000	22,177,000	266,036,000	21,098,000
3·	296,926,000	22,553,000	287,357,000	21,321,000
3·5	319,915,000	22,989,000	308,934,000	21,577,000
4·	343,403,000	23,488,000	330,805,000	21,871,000
4·5	367,456,000	23,053,000	353,008,000	22,203,000
5·	392,145,000	24,689,000	375,586,000	22,578,000
5·5	417,546,000	25,401,000	398,582,000	22,996,000
6·	443,681,000	26,135,000	422,043,000	23,461,000
6·5	470,550,000	26,869,000	446,018,000	23,975,000
7·	498,153,000	27,603,000	470,558,000	24,540,000
7·5	526,489,000	28,336,000	495,720,000	25,162,000
8·	555,560,000	29,071,000	521,554,000	25,834,000
8·5	585,365,000	29,805,000	548,122,000	26,568,000
9·	615,904,000	30,539,000	575,482,000	27,360,000
9·5	647,177,000	31,273,000	603,635,000	28,153,000
10·	679,183,000	32,006,000	632,581,000	28,946,000
10·5	711,923,000	32,740,000	662,320,000	29,739,000
11·	745,397,000	33,474,000	692,850,000	30,530,000
11·5	779,605,000	34,208,000	724,174,000	31,324,000
12·	814,546,000	34,941,000	756,290,000	32,116,000
12·5	850,219,000	35,673,000	789,199,000	32,909,000
13·	886,629,000	36,410,000	822,901,000	33,702,000
13·5	923,773,000	37,144,000	857,397,000	34,496,000
14·	961,651,000	37,878,000	892,686,000	35,289,000
14·5	1,000,263,000	38,612,000	928,768,000	36,082,000
15·	1,039,609,000	39,346,000	965,642,000	36,874,000
15·5	1,079,689,000	40,080,000	1,003,308,000	37,666,000
16·	1,120,503,000	40,814,000	1,041,766,000	38,458,000
16·5	1,162,050,000	41,547,000	1,081,017,000	39,251,000
17·	1,204,337,000	42,287,000	1,121,060,000	40,043,000
17·5	1,247,352,000	43,015,000	1,161,895,000	40,835,000
18·	1,291,101,000	43,749,000	1,203,523,000	41,628,000
18·5	1,335,584,000	44,483,000	1,245,943,000	42,420,000
19·	1,380,801,000	45,217,000	1,289,156,000	43,213,000
19·5	1,426,752,000	45,951,000	1,333,162,000	44,006,000
20·	1,473,437,000	46,685,000	1,377,961,000	44,799,000
20·5	1,520,855,000	47,418,000	1,423,553,000	45,592,000
21·	1,569,007,000	48,152,000	1,469,937,000	46,384,000
21·5	1,617,892,000	48,885,000	1,517,113,000	47,176,000
22·	1,667,513,000	49,621,000	1,565,082,000	47,969,000
22·5	1,717,857,000	50,344,000	1,613,844,000	48,762,000
23·	1,768,945,000	51,088,000	1,663,399,000	49,555,000
23·5	1,820,771,000	51,826,000	1,713,746,000	50,347,000
24·	1,873,330,000	52,559,000	1,764,885,000	51,139,000
24·5	1,926,622,000	53,292,000	1,816,817,000	51,932,000
25.	1,980,648,000	54,026,000	1,869,542,000	52,725,000

Appendix II.—concluded.

Discharge Scale for **Saiktha,** *for the years* 1872-73.

Gauge Readings.	River Rising.		River Falling.	
	Discharge for each gauge reading cubic metres in (tons) per diem.	Differences of discharges.	Discharges for each gauge reading in cubic metres (tons) per diem.	Differences of discharges.
25·5	2,035,408,000		1,923,070,000	
		54,760,000		53,528,000
26·	2,090,902,000		1,977,370,000	
		55,494,000		54,300,000
26·5	2,147,131,000		2,032,470,000	
		56,229,000		55,100,000
27·	2,204,095,000		2,088,360,000	
		56,964,000		55,890,000
27·5	2,261,793,000		2,145,050,000	
		57,698,000		56,690,000
28·	2,320,225,000		2,202,553,000	
		58,432,000		57,503,000
28·5	2,379,488,000		2,260,913,000	
		59,263,000		58,360,000
29·	2,439,631,000		2,320,203,000	
		60,143,000		59,290,000
29·5	2,500,750,000		3,380,539,000	
		61,119,000		60,336,000
30·	2,562,972,000		2,441,956,000	
		62,222,000		61,417,000
30·5	2,626,441,000		2,504,627,000	
		63,469,000		62,671,000
31·	2,691,327,000		2,568,710,000	
		64,886,000		64,083,000
31·5	2,757,830,000		2,634,372,000	
		66,503,000		65,662,000
32·	2,826,169,000		2,701,873,000	
		68,339,000		67,501,000
32·5	2,896,580,000		2,771,323,000	
		70,411,000		69,450,000
33·	2,969,344,000		2,843,013,000	
		72,764,000		71,690,000
33·5	3,044,760,000		2,917,280,000	
		75,416,000		74,200,000
34·	3,123,126,000		2,994,210,000	
		78,366,000		77,010,000
34·5	3,204,805,000		3,074,321,000	
		81,679,000		80,111,000
35·	3,290,153,000		3,157,866,000	
		85,348,000		83,545,000
35·5	3,379,513,000		3,245,202,000	
		89,360,000		87,336,000
36·	3,473,400,000		3,336,700,000	
		93,887,000		91,498,009
36·5	3,572,194,000		3,432,756,000	
		98,794,000		96,056,000
37·	3,676,372,000		3,533,786,000	
		104,178,000		101,030,000
37·5	3,786,423,000		3,640,234,000	
		110,051,000		106,448,000
38·	3,902,857,000		3,752,560,000	
		116,434,000		112,326,000
38·5	4,026,214,000		3,871,250,000	
		123,357,000		118,690,000
39·	4,157,027,000		3,996,810,000	
		130,813,000		125,560,000
39·5	4,295,944,000		4,129,770,000	
		138,917,000		132,960,000
40·	4,443,547,000		4,270,678,000	
		147,603,000		140,908,000
40·5	4,600,470,000		4,420,105,000	
		156,923,000		149,427,000
41·	4,767,380,000		4,578,650,000	
		166,910,000		158,545,000
41·5	4,944,948,000		4,746,924,000	
		177,568,000		168,274,000
42·	5,133,892,000		4,925,572,000	
		188,944,000		178,648,000
42·5	5,334,946,000		5,115,248,000	
		201,054,000		189,676,000

Appendix III.

Comparison of Measured and Scaled Discharges at **Saiktha** *for the year* 1875.

Year.	Date.	Gauge Reading.	Measured Discharge.	Scaled Discharge.	Differences.	Per Cent.
July 1875.	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19	34·48	...	2,953,884,000		
	20	34·12	2,898,560,000	2,888,024,580	− 10,535,420	− ·34
	21	33·96	...	2,855,029,500	...	...
	22	33·87	2,902,890,000	2,840,247,240	− 62,642,760	− 2·13
	23	33·58	...	2,792,615,490	...	...
	24	33·58	...	2,792,615,490	...	...
	25	33·33	2,791,430,000	2,751,553,640	− 39,876,360	− 1·40
	26	33·16	2,716,700,000	2,725,274,060	+ 8,574,060	+ ·29
	27	32·83	2,623,170,000	2,668,338,740	+ 45,168,740	+ 1·71
	28	32·80	...	2,589,567,700	...	...
	29	31·78	...	2,511,998,010	...	...
	30	31·25	...	2,440,052,310	...	...
	31	31·33	2,579,500,000	2,591,346,080	+ 11,846,080	+ ·42
August 1875.	1	32·25	...	2,723,740,420	...	...
	2	33·54	...	2,928,800,870	...	...
	3	34·33	...	3,070,006,270	...	...
	4	34·75	...	3,147,324,410	...	...
	5	34·75	3,140,610,000	3,147,324,410	+ 6,714,410	+ ·19
	6	35·00	3,179,200,000	3,198,843,340	+ 19,643,340	+ ·59
	7	35·08	3,243,270,000	3,215,414,800	− 27,855,200	− ·83
	8	35·50	...	3,302,414,940	...	...
	9	35·92	3,435,690,000	3,389,415,090	− 46,274,910	− 1·33
	10	36·50	...	3,529,926,740	...	...
	11	36·92	3,765,100,000	3,628,498,390	− 136,601,610	− 3·61
	12	37·75	3,933,580,000	3,855,473,670	− 78,106,330	− 1·98
	13	38·50	...	4,083,949,200	...	...
	14	39·10	4,425,370,000	4,281,944,860	− 143,425,140	− 3·23
	15	39·83	4,425,590,000	4,538,811,640	+ 113,221,640	+ 2·55
	16	39·92	4,427,310,000	4,568,008,910	+ 140,698,910	+ 3·16
	17	40·00	4,354,210,000	4,608,024,970	+ 253,814,970	+ 5·82
	18	39·83	4,326,190,000	4,353,720,600	+ 27,530,600	+ ·62
	19	39·50	4,271,820,000	4,243,593,000	− 28,227,000	− ·65
	20	39·08	...	4,103,430,600	...	...
	21	38·33	3,882,850,000	3,869,769,380	− 13,080,620	− ·33
	22	37·75	...	3,699,046,450	...	...
	23	36·98	3,519,830,000	3,491,746,930	− 28,083,070	− ·79
	24	36·17	3,300,400,000	3,304,783,860	+ 4,383,860	+ ·12
	25	35·50	3,179,474,000	3,157,048,320	− 22,425,680	− ·69
	26	34·58	3,051,919,000	2,972,178,260	− 79,740,740	− 2·59
	27	34·00	2,987,762,000	2,866,071,440	− 121,690,560	− 4·05
	28	34·00	2,835,000,000	2,866,071,440	+ 31,071,440	+ 1·09
	29	34·17	...	3,040,551,360	...	...
	30	34·33	3,013,325,000	3,070,006,270	+ 56,681,270	+ 1·85
	31	35·25	3,217,577,000	3,250,629,140	+ 33,052,140	+ 1·02

Appendix III.—concluded.

Comparison of Measured and Scaled Discharges at **Saiktha,** *for the year* 1875.

Year.	Date.	Gauge Reading.	Measured Discharge.	Scaled Discharge.	Differences.	Per Cent.
September 1875.	1	35·58	3,229,450,000	3,318,986,400	+ 89,536,400	+2·75
	2	36·08	3,245,310,000	3,431,355,090	+186,045,090	+5·73
	3	36·67	3,288,440,000	3,569,824,790	+281,384,790	+8 55
	4	37·04	3,569,917,000	3,665,763,520	+ 95,846,520	+2·66
	5	37·42	...	3,767,298,530	...	...
	6	37·79	3,639,610,000	3,866,161,570	+226,551,570	+6·21
	7	38·08	3,640,448,000	3,955,806,360	+315 358,360	+8·65
	8	38·17	3,643,380,000	3,983,265,540	+339,885,540	+9·30
	9	38·17	3,692,961,000	3,983,265,540	+290,304,540	+7·85
	10	38·04	3,660,180,000	3,784,263,860	+124,083,860	+3·38
	11	37·79	3,631,718,000	3,709,472,470	+ 77,754,470	+2·12
	12	37·17	...	3,547,869,100	...	...
	13	36,50	3,270,800,000	3,380,954,000	+110,154,000	+3·36
	14	35·58	3,156,050,000	3,173,450,240	+ 17,400,240	+ ·53
	15	34·62	2,991,888,000	2,979,495,976	− 12,392,024	− ·40
	16	33·75	2,774,500,000	2,820,537,550	+ 46,037,550	+1·65
	17	33·21	2,767,080,000	2,731,843,950	− 35,236,050	−1·26
	18	31·83	...	2,518,785,340	...	...
	19	30·46	...	3,336,078,580	...	...
	20	29·42	2,222,043,000	2,208,653,820	− 13,389,180	− ·58
	21	28·08	2,029,591,000	2,056,476,820	+ 26,885,820	+1·28
	22	27·42	1,987,741,000	1,985,411,049	− 2,329,951	− ·10
	23	26·00	1,831,663,000	1,839,058,300	+ 7,395,300	+ ·38
	24	24·25	1,695,793,000	1,668,123,880	− 27,669,120	−1·59
	25	24·17	1,635,875,000	1,660,498,120	+ 24,623,120	+1·47
	26	23·25	...	1,574,074,450	...	...
	27	22·33	1,515,100,000	1,499,789,580	− 15,310,420	− ·99
	28	21·75	1,451,743,000	1,437,454,105	− 14,288,895	− ·96
	29	21·42	1,429,830,000	1,408,516,670	− 21,313,330	−1·47
	30	21·17	1,382,550,000	1,386,594,370	+ 4,044,370	+ ·28
October 1875.	1	21·17	1,387,691,000	1,386,594,370	− 1,096,630	− ·07
	2	21·12	1,391,584,000	1,382,209,910	− 9,374,090	− ·64
	3	21·50	...	1,503,033,210	...	...
	4	23·17	1,603,626,000	1,665,006,810	+ 61,380,810	+3·80
	5	23·75	...	1,722,688,850	...	...
	6	23·42	1,612,970,000	1,589,846,680	− 23,123,320	−1·42
	7	23·58	1,614,400,000	1,705,782,040	+ 91,382,040	+5·63
	8	24·00	1,674,300,000	1,748,237.010	+ 73,937,010	+4·36
	9	24·04	1,594,380,000	1,752.324,690	+157,944,690	+9·85
	10	23·83	...	1,627,885,570	...	...
	11	23·83	1,577,525,000	1,627,885,570	+ 50,360,570	+3·17
	12	23·83	1,548,460,000	1,627.885,570	+ 79,425,570	+5·10
	13	24·08	1,624,179,000	1,756,412,370	+132,223,370	+8·12
	14	24·08	...	1,756,412,370	...	...
	15	23·67	1,579,913,000	1,613,041,130	+ 33,128,130	+2·09
	16	23·17	...	1,566,652,230		
	17	23·38	...	1,685,891,680		
	18	24·42	...	1,791,157,650		
	19					
	20					
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					
	31					

Appendix IV.

Discharge Scale for **Saiktha,** *for the year* 1875.

Gauge Reading.	River Rising. Discharge for each gauge reading cubic metres in (tons) per diem.	River Rising. Differences of discharge.	River Falling. Discharge for each gauge reading cubic metres in (tons) per diem.	River Falling. Differences of discharge.	Gauge Reading.
·5	21,650,760		21,161,480		·5
		21,655,553		21,166,530	
-1·0	43,306,313		42,328,010		-1·
		21,672,698		21,181,000	
- ·5	64,978,991		63,509,010		- ·5
		21,709,418		21,207,470	
0	86,688,409		84,716,470		0
		21,770,533		21,252,000	
·5	108,458,942		105,968,900		·5
		21,861,058		21,318,000	
1·0	130,320,000		127,286,915		1·
		21,988,503		21,411,000	
1·5	152,308,503		148,697,915		1·5
		22,159,742		21,535,780	
2·0	174,468,245		170,233,695		2·
		22,379,927		21,694,800	
2·5	196,848,172		191,928,495		2·5
		22,653,928		21,892,960	
3·0	219,502,100		213,821,500		3·
		23,987,447		22,135,100	
3·5	242,489,547		235,960,890		3·5
		23,393,105		22,426,200	
4·0	265,882,652		258,387,280		4·
		23,870,164		22,771,220	
4·5	289,752,816		281,161,410		4·5
		24,425,494		23,172,430	
5·0	314,178,310		304,330,800		5·
		25,065,990		23,634,610	
5·5	339,244,300		327,943,700		5·5
		25,750,946		24,163,230	
6·0	364,995,246		352,109,807		6·
		26,435,946		24,762,600	
6·5	391,431,192		376,872,437		6·5
		27,120,936		25,398,100	
7·0	418,552,128		402,270,537		7·
		27,805,936		26,034,740	
7·5	446,358,064		428,305,277		7·5
		28,490,936		26,670,800	
8·0	474,849,000		454,984,800		8·
		29,175,957		27,306,970	
8·5	504,024,957		482,291,788		8·5
		29,860,967		27,942,940	
9·0	533,885,924		510,234,728		9·
		30,546,020		28,579,130	
9·5	564,431,944		538,813,858		9·5
		31,230,939		29,215,130	
10·	595,662,883		568,028,988		10·
		31,916,017		29,851,140	
10·5	627,578,900		597,880,000		10·5
		32,600,870		30,487,210	
11·0	660,179,770		628,367,217		11·
		33,285,810		31,123,270	
11·5	693,465,580		659,490,487		11·5
		33,970,820		31,759 350	
12·0	727,436,400		691,249,830		12·
		34,655,810		32,395,410	
12·5	762,092,210		723,645,247		12·5
		35,340,990		33,031,490	
13·0	797,433,200		756,676,700		13·
		36,025,926		33,667,550	
13·5	833,459,126		790,344,282		13·5
		36,710,926		34,303,620	
14·0	870,170,052		824,647,314		14·
		37,395,926		34,939,690	
14·5	907,565,978		859,587,546		14·5
		38,080,916		35,575,750	
15·0	945,646,894		895,163,578		15·
		38,765,906		36,211,820	
15·5	984,412,800		931,375,000		15·5
		39,451,254		36,847,900	
16·0	1,023,864,054		968,222,940		16·
		40,136,244		37,484,000	
16·5	1,064,000,298		1,005,706,940		16·5
		40,821,234		38,120,000	
17·0	1,104,821,532		1,043,826,940		17·
		41,506,234		38,756,100	
17·5	1,146,327,766		1,082,583,040		17·5
		42,191,234		39,392,160	
18·0	1,188,519,000		1,121,975,000		18·
		42,875,600		40,028,220	
18·5	1,231,394,600		1,162,004,475		18·5
		43,560,600		40,654,300	
19·0	1,274,955,200		1,202,658,795		19·
		44,245,600		41,300,350	
19·5	1,319,200,800		1,243,959,145		19·5
		44,930,600		41,936,630	
20·0	1,364,131,400		1,285,895,775		20·
		45,615,600		42,577,400	
20·5	1,409,747,000		1,328,477,000		20·5
		46,300,608		43,208,570	
21·0	1,456,047,608		1,371,687,205		21.
		46,985,608		43,844,640	
21·5	1,503,033,216		1,425,531,845		21·5
		47,670,588		44,480,710	
22·0	1,550,703,804		1,470,012,555		22·
		48,355,598		45,116,770	
22·5	1,599,059,402		1,515,124,185		22·5
		49,040,598		45,752,850	
23·0	1,648,100,000		1,550,880,000		23·
		49,725,988		46,338,900	
23·5	1,697,825,988		1,597,265,900		23·5
		50,411,918		47,024,960	
24·0	1,748,237,006		1,644,293,380		24·
		51,096,018		47,661,000	
24·5	1,799,333,124		1,691,953,380		24·5
		51,780,998		48,327,810	
25·0	1,867,114,022		1,740,281,190		25·
		52,465,978		49,013,910	
25·5	1,903,580,000		1,789,283,000		25·5
		53,150,768		49,772,300	
26·0	1,956,730,000		1,839,058,295		26·
		53,862,668		50,611,420	
26·5	2,010,593,436		1,889,669,715		26·5
		54,630,848		51,550,840	
27·	2,065,224,284		1,941,218,555		27·
		55,484,648		52,610,130	
27·5	2,120,708,932		1,993,828,685		27·5
		56,451,068		53,811,330	
28	2,177,160,000		2,047,649,000		28·
		57,556,730		55,173,980	
28·5	2,234,716,730		2,102,826,067		28·5
		58,831,310		56,717,660	

Appendix IV.—concluded.

Discharge Scale for **Saiktha,** *for the year* 1875.

Gauge Reading.	River Rising.		River Falling.		Gauge Reading.
	Discharge for each gauge reading cubic metres in (tons) per diem.	Differences of discharge.	Discharge for each gauge reading cubic metres in (tons) per diem.	Differences of discharge.	
29·	2,293,548,040		2,159,543,727		29·
		60,303,850		58,464,410	
29·5	2,353,851,890		2,218,008,137		29·5
		62,001,760		60,433,770	
30·	2,415,853,650		2,278,444,907		30·
		63,951,550		62,645,330	
30·5	2,479,805,200		2,341,090,240		30·5
		66,182,712		65,103,660	
31·	2,545,987,912		2,406,115,660		31·
		68,724,542		67,873,330	
31·5	2,614,712,454		2,474,048,990		31·5
		71,604,062		70,931,330	
32·	2,686,316,516		2,544,980,320		32·
		74,847,862		74,312,300	
32·5	2,761,164,378		2,619,292,620		32·5
		78,485,622		78,035,730	
33.	2,839,650,000		2,697,352,000		33·
		82,547,156		82,123,700	
33·5	2,922,197,156		2,779,475,700		33·5
		87,058,356		86,595,740	
34·	3,009,255,512		2,866,071,440		34·
		92,046,606		91,471,440	
34·5	3,101,302,118		2,957,542,880		34·5
		97,541,226		96,993,440	
35·	3,198,843,344		3,054,536,320		35·
		103,571,656		102,512,000	
35·5	3,302,415,000		3,156,826,000		35·5
		110,164,540		108,718,700	
36·	3,412,579,540		3,265,544,700		36·
		117,347,240		115,409,300	
36·5	3,529,926,780		3,380,954,000		36·5
		125,148,840		122,604,500	
37·	3,655,075,620		3,503,558,500		37·
		133,598,740		130,325,300	
37·5	3,788,674,360		3,633,883,800		37·5
		142,723,840		138,528,000	
38·	3,931,398,200		3,772,470,000		38·
		152,551,000		147,423,300	
38·5	4,083,949,200		3,919,893,300		38·5
		163,109,800		156,839,700	
39·	4,247,059,000		4,076,733,000		39.
		174,429,320		166,860,000	
39·5	4,421,488,320		4,243,593,000		39·5
		186,536,650		177,506,500	
40·	4,608,024,970		4,421,110,000		40·
		199,458,600		188,796,000	

Appen

Daily discharges of Irrawaddy in Cubic

Year.	Days of the Month.	January.	February.	March.	April.	May.	June.
1869.	1	...	...	...	...	...	717,278,840
	2	...	...	...	...	...	717,278,840
	3	...	...	...	...	...	651,685,360
	4	...	...	...	...	...	717,278,840
	5	...	...	...	...	...	756,778,160
	6	...	...	...	...	...	797,075,500
	7	...	...	...	...	...	820,136,560
	8	...	...	...	...	...	856,044,600
	9	...	...	...	...	...	874,249,600
	10	...	...	...	...	...	874,249,600
	11	...	...	...	...	...	892,454,600
	12	...	...	...	...	...	929,833,480
	13	...	...	...	...	...	971,499,280
	14	...	...	...	...	...	1,013,640,640
	15	...	...	...	...	...	1,147,440,240
	16	...	...	...	...	...	1,232,246,420
	17	...	...	...	...	...	1,319,975,340
	18	...	...	...	...	...	1,388,035,720
	19	...	...	...	...	...	1,457,564,100
	20	...	...	...	...	...	1,504,249,100
	21	...	...	...	...	...	1,528,559,320
	22	...	...	...	...	...	1,528,559,320
	23	...	...	...	...	...	1,407,528,340
	24	...	...	...	...	...	1,377,961,000
	25	...	...	...	...	...	1,362,729,340
	26	...	...	...	...	...	1,489,309,900
	27	...	...	...	...	...	1,520,855,000
	28	...	...	...	...	...	1,600,787,320
	29	...	...	...	...	...	1,634,763,140
	30	...	...	...	...	...	1,675,452,360
	31	...	...	...	...	...	
Total	...	...	...	...	...	...	34,765,499,860
1870.	1	...	211,943,620	170,784,420	222,031,240	224,593,480	296,926,000
	2	...	209,469,300	169,554,360	209,881,520	210,293,740	313,615,220
	3	...	208,644,860	169,554,360	199,988,240	203,286,000	317,223,700
	4	...	207,820,420	163,404,060	188,858,300	197,514,920	323,673,080
	5	...	206,583,760	160,540,960	160,949,220	190,919,400	323,673,080
	6	...	205,759,320	159,316,180	177,673,640	179,394,840	309,371,420
	7	...	202,461,560	155,233,580	170,784,420	174,474,600	329,779,960
	8	...	200,400,460	153,192,280	169,144,340	174,474,600	365,951,480
	9	...	198,339,360	151,967,500	165,454,160	187,441,000	443,681,000
	10	...	195,041,600	150,742,720	162,584,020	188,295,080	527,651,840
	11	...	192,156,060	149,109,680	169,630,560	179,394,800	611,017,760
	12	...	190,507,180	147,884,900	182,331,160	179,394,840	663,180,000
	13	...	188,446,080	145,843,600	201,533,320	205,376,680	706,068,040
	14	...	188,033,860	145,027,080	211,782,280	233,401,560	729,998,960
	15	...	185,148,320	142,169,260	211,782,280	252,196,000	763,472,960
	16	...	183,911,660	141,761,000	198,751,580	257,878,040	820,136,560
	17	...	190,003,240	140,947,200	194,217,160	270,990,440	862,598,400
	18	...	192,138,440	139,319,600	186,384,980	280,236,780	910,659,600
	19	248,699,360	193,419,560	136,471,300	181,034,920	248,283,120	986,650,480
	20	238,665,900	188,033,860	135,657,500	176,934,720	270,553,360	1,039,609,000
	21	238,665,900	184,323,880	134,843,700	173,244,540	285,649,500	1,096,014,600
	22	234,484,500	182,264,980	133,216,100	181,483,520	269,020,940	1,134,379,760
	23	232,811,940	179,394,840	137,284,240	187,868,040	282,041,020	1,154,786,760
	24	229,466,820	176,934,720	137,284,240	194,700,680	291,062,220	1,067,148,280
	25	227,376,120	174,064,580	137,284,240	194,700,680	308,202,500	1,162,050,000
	26	224,867,280	173,654,560	139,702,480	188,033,860	311,810,980	1,204,337,000
	27	220,599,240	172,424,500	144,390,920	194,700,680	294,606,140	1,252,601,880
	28	218,125,920	171,604,460	150,271,080	206,230,760	287,357,000	1,291,101,000
	29	216,064,820	...	166,667,320	218,614,920	280,534,280	1,365,427,220
	30	213,591,500	...	195,127,720	222,031,240	280,534,280	1,516,387,200
	31	212,767,060	...	218,614,920		290,160,100	
Total	...	2,950,186,360	5,352,928,040	4,723,168,500	5,7[illegible]3,339,980	7,489,372,280	23,889,172,240

dix V.

Metres at **Saiktha** *or* **Myanoung.**

July.	August.	September.	October.	November.	December.	Days of the Month.	Year.
1,768,945,000	2,329,689,400	2,807,168,000	2,281,659,880	1,176,048,520	...	1	1869.
1,891,200,060	2,270,399,400	2,771,323,000	2,349,441,000	1,101,038,500	...	2	
2,090,902,000	2,047,001,400	2,746,423,660	2,439,631,000	1,028,690,280	...	3	
1,958,908,000	2,013,208,000	2,735,623,500	2,521,905,480	965,642,000	...	4	
1,950,220,000	1,958,908,000	2,712,673,160	2,604,038,520	910,330,500	...	5	
1,913,831,000	2,090,912,000	2,668,122,500	2,648,5 2,240	863,043,240	...	6	
1,877,978,000	2,137,516,960	2,590,498,220	2 691,327,000	828,293,320	...	7	
1,877,978,000	2,194,980,760	2,514,880,280	2,734,151,760	811,442,320	...	8	
2,063,155,000	2,241,691,240	2,421,074,220	2,791,999,500	794,591,320	...	9	
2,118,649,000	2,300,358,120	2,329,689,400	2,826,169,000	756,290,000	...	10	
2,204,095,000	2,389,110,880	2,250,855,520	2,849,404,260	735,093,440	...	11	
2,271,142,120	2,449,253,880	2,211,753,480	2,871,272,740	708,115,000	...	12	
2,409,559,500	2,510,715,520	2,349,441,000	2,701,873,000	682,469,800	...	13	
2,479,325,380	2,553,016,480	2,355,284,200	2,568,710,000	667,204,800	...	14	
2,562,972,000	2,604,038,520	2,361,127,400	2,421,074,220	651,685,360	...	15	
2,615,288,480	2,691,327,000	2,379,488,000	2,222,104,020	637,212,360	...	16	
2,691,327,000	2,802,933,740	2,409,559,500	1,995,832,000	622,739,360	...	17	
2,734,151,760	2,908,222,240	2,276,328,400	1,713,746,000	608,266,360	...	18	
2,781,065,260	3,005,726,000	2,226,704,260	1,655,470,200	...	...	19	
2,837,103,240	3,096,481,560	2,164,601,020	1,917,479,560	...	...	20	
2,871,272,740	3,174,847,560	2,164,601,020	1,962,279,160	...	...	21	
2,944,604,240	3,247,479,000	2,300,358,120	2,016,305,160	...	...	22	
2,994,083,760	3,276,497,320	2,329,574,120	2,016,305,160	...	...	23	
3,057,298,560	3,319,171,320	2,389,110,880	2,026,029,840	...	...	24	
3,071,414,440	3,332,827,000	2,419,182,380	1,843,179,500	...	...	25	
2,867,387,600	3,157,866,000	2,270,399,400	1,747,497,740	...	...	26	
2,746,423,660	3,122,777,100	2,231,304,500	1,592,904,020	...	...	27	
2,712,673,160	3,065,139,200	2,202,553,000	1,519,031,760	...	...	28	
2,678,922,660	3,026,634,200	2,183,001,980	1,446,745,000	...	...	29	
2,600,751,500	2,943,463,400	2,154,250,480	1,348,393,660	...	...	30	
2,462,837,780	2,867,387,600	...	1,260,635,420	...	...	31	
76,105,405,900	83,129,560,800	71,926,954,600	67,585,097,800	14,548,196,480	...	Total	...
1,675,452,360	3,488,421,920	3,426,456,500	2,775,624,400	1,168,555,480	570,095,500	1	1870.
1,811,858,920	3,510,954,800	3,276,311,320	2,634,372,000	947,205,000	595,748,260	2	
1,935,266,160	3,510,954,800	3,234,733,400	2,390,365,720	887,039,760	605,520,740	3	
2,035,627,760	3,512,832,540	3,199,638,500	2,222,104,020	839,752,000	559,613,200	4	
2,114,209,480	3,351,339,680	3,458,629,840	2,064,886,200	804,027,880	540,154,480	5	
2,175,613,000	3,336,700,000	3,025,094,000	1,958,908,000	772,348,000	517,420,560	6	
2,223,462,760	3,320,230,360	2,929,601,600	1,930,672,000	747,939,840	579,979,640	7	
2,241,691,240	3,305,590,680	2,818,638,400	1,930,672,000	720,937,600	470,558,000	8	
2,261,793,000	3,290,951,000	2,707,273,080	1,923,070,000	703,230,200	456,324,800	9	
2,300,358,120	3,245,202,000	2,590,498,220	1,895,904,500	687,965,200	439,873,360	10	
2,340,091,880	3,192,954,900	2,493,546,280	1,851,615,500	667,204,800	427,673,640	11	
2,397,530,900	3,119,435,300	2,449,326,040	1,843,179,500	736,693,760	418,289,240	12	
2,469,702,500	3,011,232,200	2,411,247,500	1,966,601,240	770,837,240	410,312,500	13	
2,531,861,000	2,890,328,400	2,541,816,520	1,843,179,500	667,204,800	398,582,000	14	
2,534,349,800	2,758,573,840	2,626,441,000	1,786,363,380	642,422,640	390,487,480	15	
2,664,074,880	2,634,372,000	2,751,022,120	1,717,837,120	622,739,360	383,262,520	16	
2,734,151,760	2,514,880,280	2,854,871,380	1,663,399,000	598,464,400	373,779,760	17	
2,815,234,760	2,421,074,220	2,957,701,760	1,601,538,440	579,859,600	667,909,480	18	
2,883,573,760	2,359,334,400	3,005,726,000	1,503,333,480	568,368,400	364,297,000	19	
2,963,522,880	2,349,848,000	3,083,943,000	1,430,046,760	561,802,000	356,620,480	20	
3,030,465,760	2,516,927,720	3,218,460,680	1,374,377,080	552,499,600	353,008,000	21	
3,096,481,560	2,594,083,000	3,074,321,000	1,336,745,920	543,254,560	347,426,960	22	
3,156,039,720	2,680,945,240	3,017,393,000	1,303,848,420	530,337,560	341,740,500	23	
3,218,460,680	2,781,065,260	2,923,440,800	1,303,848,420	521,554,000	338,241,140	24	
3,261,134,680	2,887,674,100	2,843,013,000	1,442,624,900	512,770,440	334,304,360	25	
3,296,980,840	2,963,522,880	2,818,638,400	1,480,906,600	504,503,560	329,055,320	26	
3,332,827,000	3,030,465,760	2,969,344,000	1,512,652,400	491,171,600	323,368,860	27	
3,379,513,000	3,116,856,720	2,994,083,760	1,374,377,080	491,171,600	317,682,400	28	
3,394,534,920	3,230,409,400	2,858,784,800	1,281,377,660	531,140,360	313,745,620	29	
3,411,434,580	3,322,585,240	2,817,204,600	1,185,206,680	549,745,800	308,934,000	30	
3,441,478,420	3,411,434,580	...	1,094,631,620	...	305,266,640	31	
83,128,778,160	93,661,181,220	87,377,200,500	53,624,269,540	19,922,747,040	12,839,276,440	Total	...

Appendix

Detail discharges of Irrawaddy in Cubic

Year.	Days of the month.	January.	February.	March.	April.	May.	June.
1871.	1	303,560,960	211,942,620	174,287,080	226,957,980	314,183,040	641,556,760
	2	299,723,180	209,881,520	189,149,160	218,125,920	305,266,640	843,896,440
	3	295,885,400	207,408,200	204,949,640	213,591,500	305,266,640	1,093,565,760
	4	292,900,460	204,934,880	207,938,920	213,591,500	305,266,640	1,269,226,500
	5	288,636,260	203,286,000	196,278,260	223,739,400	305,266,640	1,298,100,840
	6	285,651,320	202,461,560	188,446,080	233,838,640	305,266,640	1,182,709,000
	7	281,813,540	202,461,560	179,394,840	246,951,040	298,017,500	1,161,895,000
	8	278,402,180	201,637,120	174,064,580	252,196,000	290,768,360	1,060,995,000
	9	274,564,400	199,988,240	172,424,500	242,847,300	280,960,700	1,060,995,000
	10	271,579,460	196,690,480	172,424,500	232,811,940	270,579,460	984,079,000
	11	269,447,360	192,980,500	184,023,440	225,285,420	256,645,920	959,742,160
	12	266,888,840	191,919,400	188,081,560	220,599,240	244,938,000	1,093,565,760
	13	262,499,880	188,858,300	190,857,320	218,950,360	241,592,880	1,204,337,000
	14	260,409,180	185,972,760	205,376,680	230,342,000	237,829,620	1,319,975,340
	15	257,900,340	181,034,920	238,209,440	264,434,240	246,951,040	1,380,801,000
	16	255,391,500	178,164,780	272,301,680	323,673,080	259,626,360	1,274,463,580
	17	253,300,800	186,563,360	282,492,080	377,825,380	296,926,000	1,274,463,580
	18	250,373,820	179,394,840	264,172,440	408,439,740	367,456,000	1,365,566,280
	19	247,864,980	177,344,740	248,283,120	426,431,900	470,550,000	1,387,131,380
	20	244,519,860	174,474,600	235,320,780	439,499,400	477,726,780	1,400,696,480
	21	239,502,180	171,604,460	223,072,560	449,953,400	477,726,780	1,410,644,220
	22	237,829,620	169,964,380	212,767,060	452,566,900	416,412,360	1,645,679,760
	23	234,484,500	169,144,340	206,583,760	422,043,000	447,862,600	1,802,663,080
	24	232,393,800	169,144,340	203,286,000	410,312,500	465,634,400	2,000,097,360
	25	229,466,820	176,403,680	203,286,000	396,357,760	477,726,780	2,175,613,000
	26	226,539,840	177,673,640	223,739,400	383,262,520	491,528,280	2,312,044,520
	27	221,423,680	171,604,460	255,692,640	367,909,480	505,329,780	2,407,153,780
	28	220,599,240	167,914,280	280,687,840	353,008,000	514,162,740	2,472,108,220
	29	217,713,700	...	280,687,840	338,241,140	523,547,760	2,510,705,520
	30	216,064,820	...	257,900,340	325,555,960	560,211,360	2,541,816,520
	31	214,415,940	...	241,592,880	...	593,305,140	...
Total ...		7,931,747,860	5,248,853,960	6,768,772,420	9,339,342,640	11,555,532,840	44,536,287,840
1872.	1	375,586,000	262,499,880	199,988,240	216,889,260	219,469,000	504,503,560
	2	371,973,520	258,736,620	203,286,000	213,591,500	237,679,200	491,171,600
	3	364,297,000	255,391,500	212,209,320	203,286,000	227,376,120	491,171,600
	4	356,620,480	248,283,120	216,052,680	199,988,240	227,376,120	478,901,600
	5	353,008,000	244,938,000	206,583,760	196,278,260	244,765,640	466,631,600
	6	349,176,640	241,592,880	206,583,760	196,278,260	300,534,480	437,996,480
	7	341,740,500	237,829,620	206,583,760	192,980,500	404,489,500	479,935,020
	8	334,304,360	234,484,500	203,286,000	189,682,740	465,634,400	479,935,020
	9	330,805,000	224,031,000	199,988,240	228,863,880	465,634,400	426,265,980
	10	327,305,640	220,599,240	196,278,260	210,293,740	498,153,000	470,550,000
	11	323,368,860	216,889,260	196,278,260	263,123,000	498,153,000	511,954,500
	12	319,869,500	213,591,500	192,980,500	266,619,640	462,214,400	516,923,040
	13	319,869,500	210,293,740	189,682,740	277,981,480	446,018,000	526,498,000
	14	335,417,080	230,342,000	189,682,740	277,981,480	462,705,200	541,024,500
	15	339,644,920	233,838,640	189,682,740	262,499,880	507,538,020	565,444,140
	16	323,368,860	233,838,640	189,682,740	248,283,120	466,631,600	606,131,520
	17	319,869,500	237,679,200	201,410,360	234,484,500	466,631,600	647,177,000
	18	316,370,140	244,765,640	201,410,360	224,031,000	498,153,000	690,065,040
	19	308,934,000	252,196,000	201,410,360	216,889,260	462,705,200	717,948,320
	20	305,266,640	255,692,640	201,410,360	210,293,740	450,435,200	723,304,160
	21	301,428,860	259,626,360	189,682,740	203,286,000	446,018,000	652,264,280
	22	298,017,500	248,283,120	179,394,840	196,278,260	498,153,000	642,422,640
	23	294,606,140	237,829,620	179,394,840	196,278,260	536,373,140	700,947,080
	24	290,768,360	231,139,380	179,394,840	196,278,260	590,862,000	717,948,320
	25	287,357,000	224,031,000	179,394,840	192,980,500	626,287,260	942,712,000
	26	283,945,640	216,889,260	190,857,320	185,972,760	580,406,800	1,003,313,640
	27	283,945,640	213,591,500	198,117,000	185,972,760	575,482,000	1,162,050,000
	28	280,107,860	206,583,760	216,052,680	198,117,000	561,802,000	1,262,226,660
	29	276,696,500	203,286,000	233,838,640	212,209,320	548,122,000	1,481,840,300
	30	273,285,140	...	241,269,000	219,469,000	530,337,560	1,667,513,000
	31	266,036,000	...	220,599,240	...	508,637,000	...
Total ...		9,852,990,780	6,798,773,620	6,212,467,160	6,517,161,600	14,014,777,860	21,036,761,600

V.—continued.

Metres at **Saiktha** *or* **Myanoung.**

July.	August.	September.	October.	November.	December.	Days of the month.	Year.
2,300,044,400	3,844,640,000	3,361,845,320	2,493,546,280	1,439,323,560	622,739,360	1	
2,135,307,600	3,844,227,560	3,411,434,580	2,451,782,720	1,786,314,920	618,108,000	2	
1,986,058,000	3,979,703,440	3,473,400,000	2,340,361,600	1,899,609,500	618,108,000	3	
1,931,758,000	3,979,703,440	3,535,365,420	2,250,855,520	2,016,305,160	613,476,640	4	
1,931,758,000	4,026,214,000	3,558,862,480	2,173,801,500	2,099,781,040	593,539,600	5	
2,099,781,040	4,091,620,500	3,640,951,480	2,116,305,000	2,127,528,040	579,859,600	6	
2,194,980,760	4,091,620,500	3,659,703,520	2,097,302,400	1,968,682,000	561,802,000	7	
2,310,875,880	3,871,250,000	3,693,040,480	2,051,472,600	1,913,831,000	543,254,560	8	
2,430,008,120	3,808,723,000	3,805,052,440	2,051,472,600	1,816,817,000	595,748,260	9	
2,510,705,520	3,696,397,000	3,826,010,560	2,041,412,400	1,671,327,800	615,904,000	10	
2,584,127,480	3,568,136,200	3,618,651,200	2,194,980,760	1,533,422,460	566,179,600	11	
2,636,822,760	3,448,920,800	3,549,950,800	2,051,472,600	1,389,128,840	557,424,400	12	
2,745,831,240	3,351,341,480	3,517,621,200	1,941,532,000	1,245,943,000	538,604,440	13	
2,871,272,740	3,259,841,680	3,499,435,800	1,825,253,000	1,189,369,480	524,292,440	14	
2,932,962,000	3,171,233,200	3,487,106,200	1,713,746,000	1,101,038,500	508,637,000	15	
3,017,368,240	3,058,978,400	3,382,449,000	1,680,247,700	1,028,690,280	491,171,600	16	1871
3,083,943,000	3,006,611,600	3,276,311,320	1,680,247,700	971,541,840	474,484,400	17	
3,135,664,560	2,929,601,600	3,020,473,400	1,680,247,700	922,328,760	470,558,000	18	
3,174,847,560	2,890,328,400	2,917,280,000	1,581,404,860	851,210,680	458,288,000	19	
3,188,953,440	2,600,751,500	2,724,823,340	1,709,194,640	834,359,680	454,361,600	20	
3,204,805,000	2,504,627,000	2,546,921,780	1,709,194,640	811,442,320	454,361,600	21	
3,233,823,320	2,472,664,500	2,526,415,220	1,786,314,920	697,734,800	445,018,000	22	
3,261,134,680	2,604,038,520	2,482,491,220	1,820,771,000	697,734,800	437,527,260	23	
3,290,153,000	2,680,945,240	2,472,664,500	1,829,180,440	718,495,200	430,019,740	24	
3,346,482,680	2,757,830,000	2,462,837,780	1,705,025,000	697,734,800	418,289,240	25	
3,379,513,000	2,883,573,760	2,451,782,720	1,688,176,500	682,496,800	418,289,240	26	
3,441,478,420	2,980,986,240	2,584,127,480	1,655,470,200	667,204,800	414,066,260	27	
3,535,365,420	3,057,298,560	2,626,441,000	1,589,066,500	656,895,640	402,335,760	28	
3,588,862,480	3,149,770,440	2,669,265,760	1,524,788,040	637,212,360	394,551,520	29	
3,728,461,000	3,218,460,680	2,669,265,760	1,477,358,440	627,947,640	386,875,000	30	
3,763,881,520	3,303,808,680	...	1,454,166,440	...	379,198,480	31	
88,977,030,860	102,173,847,920	94,451,981,760	58,366,151,900	36,701,425,700	15,588,073,600		
2,128,637,920	2,524,681,720	3,302,843,760	2,861,374,500	1,700,740,040	598,567,460	1	
2,214,348,520	2,483,318,860	3,345,202,000	2,919,111,520	1,572,883,920	584,490,960	2	
2,390,313,740	2,615,016,580	3,171,839,760	2,954,317,020	1,572,883,920	575,482,000	3	
2,804,300,520	2,483,318,860	3,034,265,500	2,969,344,000	1,959,663,040	561,406,000	4	
2,815,234,760	2,801,721,980	2,917,213,000	3,031,185,120	1,816,817,000	552,372,880	5	
2,668,122,500	2,933,051,260	2,817,160,000	2,843,013,000	1,755,030,540	543,339,760	6	
2,600,751,500	3,031,185,120	2,747,710,000	2,817,160,000	1,679,510,040	532,181,200	7	
2,526,415,220	3,177,034,140	2,712,985,000	2,806,048,000	1,572,883,920	521,554,000	8	
2,483,719,560	3,217,873,640	2,677,708,920	2,782,435,000	1,460,938,440	514,339,880	9	
2,453,011,060	3,245,644,500	2,644,877,920	2,758,822,000	1,311,159,000	508,301,000	10	
2,453,011,060	3,290,153,000	2,634,372,000	2,724,097,000	1,252,730,200	499,745,920	11	
2,703,006,480	3,290,153,000	2,791,081,500	2,667,203,000	1,182,312,500	493,203,000	12	
2,779,110,960	3,127,194,260	2,655,383,840	2,622,552,840	1,061,391,500	487,164,920	13	
2,861,374,500	3,059,901,020	2,622,552,840	2,589,721,840	1,022,141,000	478,609,840	14	
2,969,344,000	2,954,313,000	2,579,215,920	2,579,215,920	971,668,560	470,558,000	15	
3,044,760,000	2,880,113,000	2,568,710,000	2,712,607,960	916,500,120	461,841,500	16	1872
3,068,893,120	2,843,013,000	2,524,681,720	2,768,470,480	885,683,720	453,690,000	17	
3,090,009,600	2,817,160,000	2,462,010,720	2,861,374,500	845,668,360	443,620,500	18	
3,106,601,120	2,806,048,000	2,390,192,760	2,931,785,500	816,184,380	437,866,500	19	
3,123,126,000	2,954,317,020	2,279,588,200	2,969,344,000	789,199,000	434,030,500	20	
2,961,733,000	2,993,477,120	2,173,395,000	3,007,052,000	761,555,440	422,043,300	21	
2,917,213,000	3,031,185,120	2,041,286,000	2,843,013,000	739,836,000	379,265,360	22	
2,917,213,000	3,082,468,000	1,905,870,000	2,758,822,000	718,535,680	432,278,580	23	
2,917,213,000	3,149,263,280	2,035,408,000	2,644,877,920	702,873,680	402,261,360	24	
3,056,826,560	3,290,153,000	2,147,131,000	2,644,877,920	679,568,620	394,442,720	25	
2,866,757,000	3,318,745,200	2,320,225,000	2,369,678,520	662,320,000	388,923,680	26	
2,793,547,000	3,363,428,200	2,418,601,580	2,241,070,600	647,450,500	387,084,000	27	
2,736,598,000	3,408,108,200	2,531,309,500	2,041,286,000	632,581,000	379,265,360	28	
2,701,873,000	3,438,490,600	2,626,441,000	1,886,670,960	617,711,500	375,586,000	29	
2,688,214,840	3,473,400,000	2,779,110,960	1,755,030,540	607,013,360	367,661,980	30	
2,688,214,840	3,473,400,000	...	1,555,797,320	...	364,109,500	31	
85,529,495,380	94,557,343,680	77,758,373,400	81,917,359,980	32,915,434,980	14,445,287,360		

Appendix

Daily discharges of Irrawaddy in Cubic

Year.	Days of the month.	January.	February.	March.	April.	May.	June.
1873.	1	360,112.960	281,648,520	181,444,940	171,604,460	253,970,160	255,744,320
	2	354,784,240	274,475,200	181,444,940	176,827,000	267,921,320	270,824,680
	3	350,787.700	269,411,680	180,624,900	209,625,200	306,581,380	244,938,000
	4	345,458.980	264,770,120	178,984,820	241,132 000	312,098,740	231,084,300
	5	341,906,500	261,394.440	208,762,000	279,695,480	318,075,880	229,839,600
	6	337,909,960	258,018,760	213,941,200	290,783,980	323,593 240	244,584,800
	7	334,357,480	254,221,120	217,394,000	276,585,000	311,523,240	269,494,060
	8	330,805,000	251,689,360	219,552,000	266,036,000	308,934,000	339,225,760
	9	326.627,140	248,313,680	222,141,600	253,799,160	301,597,820	408,909,660
	10	322,311,740	242,701.500	224,731,200	243,531,300	298,145,500	466,250,960
	11	319,722,500	242,701,500	237,679,200	234,403,500	293,830,100	600,267,500
	12	314,112,480	241,041,900	240,268,800	227,350,200	289.946,240	762,501,000
	13	308,934,000	240,627,000	243,721,600	220,711,800	304,742,260	855,926,680
	14	306,776,300	240,212,100	227,350,200	215,318,100	315,776,980	987,134,920
	15	305,050,140	236,063.100	218,637.300	211.584,000	323,593,240	1,099,729,000
	16	303,323,980	232,329,000	212,828,700	210,339,300	310,660,160	1,186,147 260
	17	301,597,820	228,180,000	203,286,000	209,094,600	292,535,480	1,313,342,500
	18	299,871,660	227,350,200	181,854,960	209,094,600	281,648,520	1,434,104,160
	19	298,145,500	224,860,800	177,344,740	216,099,200	273,209,320	1,601,271,100
	20	296,419,340	221,126,700	211,351,600	207,435,000	263,926,200	1,812,478,840
	21	294.261,640	217,807,500	221,278,400	204,115,800	257,174,840	1,949,004,640
	22	292.535,480	215,318,100	224,731,200	178,984,820	250,845,440	2,081,406,400
	23	287,357.000	211,584,000	213,658,500	174.064.580	259,736,180	2,156,127,640
	24	283,336,360	219,552,000	208,264,800	172,834,520	266,832,820	2,208,710,840
	25	279,960,680	219,552,000	208.264,800	179,366,920	270,381,140	2.242,175,680
	26	276,585.000	228,184,000	219,552,000	186,563,360	251.689,360	2,290,642,000
	27	294,332,300	206,605,200	220,415,200	217,825,600	241,041,900	2,340,374,420
	28	298,765,120	204,115,800	210,339,300	228,184.000	230.669,400	2,374,746,960
	29	300,604,240	...	203,286.000	235,521,200	224,031,000	2,449,410,040
	30	289,083,160	...	178,984,820	246,311,200	218,637,300	2,454,299,560
	31	285.024,200	...	174,884,620	...	240,268,800	...
Total	...	9,640,860,600	6,663,855,280	6,466,004,340	6,594,821,880	8,663,618,960	37,160,697,280
1874.	1	252,046,380	175,704,660	162,174,000	345,282,040	450,476,100	772,348,000
	2	248,283,120	172,424,500	160,540,960	329,055,320	456,748,500	687,965,200
	3	244,938,000	169,964,380	158,907,920	347.161,080	470,550,000	622,739,360
	4	241,592,880	169,144,340	158,907,920	373,875,140	484.351,500	573,293,200
	5	237,829,620	176,827,000	156,050,100	404,489,500	446,018,000	684,303,960
	6	234,484,500	176,827,000	161,199,920	412,883,760	428,142,860	734.015,840
	7	232,811,940	170,784,420	162,881,280	414,858,880	396,357,760	767,489,840
	8	231.139,380	169,144,340	381,775,620	392,745,280	375,586,000	779,605,000
	9	227,376,120	176,827,000	341,740,500	364,297,000	345,239,860	703,230,200
	10	227,376,120	169,144,340	189,682,740	356,620,480	334,304,360	637,212,360
	11	225,703,560	176,827,000	182,675,000	319,869,500	323,368.860	627.947,640
	12	223,072,560	180,213,560	181,034,920	306,972,320	330,805,000	589.162,000
	13	220,599,240	184,023,440	172,424,500	296,311,820	358,905,080	566,179,600
	14	216,889,260	184,023,440	162,174,000	296,311,820	336,491,460	552,499,600
	15	213,591,500	177,754,760	158,907,920	331,659,000	355,147,000	525,687,440
	16	210,293,740	169,144,340	157,274,880	349,509,880	447.862,600	517 420,560
	17	206,583,760	162,174,000	155,233,580	353,267,960	456,748,500	560,211,360
	18	203,286,000	162,174,000	148,701,420	336,491,460	467,725,200	570,095,500
	19	201,637,120	180,213,560	147,068,380	329,055,320	498,153,000	615,904,000
	20	197,102,700	172,424,500	152,372,780	319,869,500	641,556,760	700,306,960
	21	190,507,180	169,964,380	152,372,780	337,765,880	728,660,000	767,489,840
	22	185,972.760	168,734,320	152,372,780	323,368,860	779,605,000	820,136,560
	23	182,675,000	167,504,260	241,262,000	339,644,920	823,630,660	886,629,000
	24	194,700,680	165,454,160	244,765,640	345,282,040	843,896,440	974,529,520
	25	219,469,000	163,814,080	210,293,740	349,509,880	886,629,000	1,026,231,360
	26	230,342,000	162.174,000	206,583,760	353,267,960	955,590,520	1,134,379,760
	27	220,599,240	173,440,440	241,269,000	379,800,500	993,468,520	1,183,193,500
	28	210,293,740	165,454,160	266,619,640	402,514,380	910,330.500	1,269,226,500
	29	199,988,240	...	289,257,980	421,727,600	1,013,640,640	1,380,801,000
	30	192,980,500	...	308,202,500	439,499,400	1,019,936,000	1,576,711,320
	31	182,675,000	...	327,900,920	...	875,041,500	...
Total	...	6,706,840,840	4,812,304,380	6,491,819,560	10,672,768,480	18,234,967,180	23,806,945,980

V.—continued.

Metres at **Saiktha** *or* **Myanoung.**

July.	August.	September.	October.	November.	December.	Days of the Month.	Year.
2,320,203,000	2,399,637,420	2,957,701,760	1,585,378,680	1,688,176,500	454,361,600	1	1873.
2,270,250,600	2,484,859,060	2,777,058,200	1,667,513,000	1,638,621,500	449,944,400	2	
2,202,553,000	2,641,673,560	2,712,673,160	1,760,770,920	1,565,082,000	446,018,000	3	
2,117,706,000	2,724,578,500	2,600,751,500	1,811,858,920	1,548,772,540	437,527,260	4	
2,051,204,000	2,872,640,260	2,472,664,500	1,881,739,440	1,493,129,000	425,796,760	5	
1,931,644,480	2,981,410,560	2,359,334,400	1,891,200,060	1,389,608,740	410,312,500	6	
1,887,741,520	3,082,468,000	2,235,904,740	1,756,702,760	1,245,943,000	402,335,760	7	
1,790,851,000	3,150,896,860	2,160,000,780	1,721,928,240	1,147,488,380	400,458,880	8	
1,713,746,000	3,191,736,360	2,154,250,480	1,680,247,700	1,147,488,380	394,551,520	9	
1,654,804,080	3,227,675,120	2,329,574,120	1,646,550,300	1,035,612,720	388,681,240	10	
1,589,463,000	3,074,321,000	2,409,559,500	1,596,741,540	965,642,000	385,068,760	11	
1,576,784,880	3,013,436,640	2,449,253,880	1,581,404,860	898,332,240	379,198,480	12	
1,846,684,000	2,897,921,000	2,469,702,500	1,577,553,940	839,752,000	370,167,280	13	
1,930,585,360	2,728,435,000	2,469,702,500	1,557,400,960	967,711,480	364,297,000	14	
2,058,407,200	2,682,961,880	2,310,716,600	1,524,788,040	791,895,160	354,814,240	15	
2,228,328,160	2,591,035,080	2,250,855,520	1,462,515,560	741,516,640	349,176,640	16	
2,370,005,920	2,494,599,640	2,222,104,020	1,458,804,840	692,850,000	343,490,180	17	
2,531,309,500	2,451,983,360	2,193,352,520	1,561,302,680	667,204,800	338,241,140	18	
2,594,706,500	2,390,192,760	2,088,360,000	1,585,378,680	651,685,360	330,805,000	19	
2,691,327,000	2,340,717,240	2,079,417,600	1,634,763,140	642,422,640	319,869,000	20	
2,713,938,020	2,320,203,000	1,991,488,000	1,680,414,460	618,108,000	310,683,000	21	
2,724,578,500	2,320,203,000	1,851,615,500	1,807,771,880	579,859,600	303,560,960	22	
2,568,710,000	2,521,530,460	1,663,399,000	1,873,330,000	552,499,600	294,606,140	23	
2,525,935,140	2,648,020,460	1,541,097,500	1,891,200,060	543,254,560	285,651,320	24	
2,446,969,680	2,679,754,960	1,477,358,440	1,764,885,000	525,687,440	278,402,180	25	
2,290,093,000	2,735,218,980	1,400,360,500	1,688,176,500	508,637,000	274,990,820	26	
2,260,913,000	2,801,721,980	1,303,848,420	1,613,844,000	495,720,000	271,579,460	27	
2,231,733,000	2,861,374,500	1,296,070,080	1,802,663,080	478,901,600	267,741,680	28	
2,379,488,000	2,893,763,560	1,296,070,080	1,680,247,700	466,531,600	264,172,440	29	
2,460,411,460	2,920,519,740	1,489,309,900	1,820,771,000	458,288,000	260,827,320	30	
2,260,913,000	2,920,519,740	...	1,696,105,300	...	255,301,500	31	
68,222,287,000	85,100,009,680	63,013,555,700	52,263,959,240	26,986,522,480	10,812,722,460		
1,768,945,000	2,116,305,000	2,701,708,760	2,896,580,000	1,508,899,560	508,637,000	1	1874.
2,035,408,000	2,060,415,000	2,757,830,000	2,657,322,340	1,423,553,000	495,720,000	2	
2,063,155,000	1,861,106,000	2,791,999,500	2,611,004,780	1,325,454,920	480,864,800	3	
2,099,781,040	1,782,272,260	2,802,933,740	2,526,416,220	1,264,092,460	478,901,600	4	
2,137,516,960	1,671,327,800	2,809,767,640	2,411,247,500	1,176,048,520	462,214,400	5	
1,995,832,000	1,646,550,300	2,678,922,660	2,340,361,600	1,117,856,560	446,018,000	6	
2,127,528,040	1,638,621,500	2,657,322,340	2,494,962,560	1,060,995,000	437,527,260	7	
2,175,613,000	1,777,119,080	2,536,668,500	2,594,083,000	1,041,766,000	430,019,740	8	
2,184,727,240	1,786,314,920	2,763,297,120	2,594,083,000	1,019,460,360	430,019,740	9	
2,060,415,000	1,786,314,920	2,578,963,280	2,380,539,000	965,642,000	416,412,360	10	
2,194,980,760	1,855,459,940	2,472,664,500	2,305,973,400	947,205,000	406,558,740	11	
2,194,980,760	1,864,920,560	2,380,539,000	2,226,704,260	1,030,165,960	396,357,760	12	
2,213,209,240	1,873,330,000	2,329,689,400	2,183,001,980	1,036,461,320	390,487,480	13	
2,232,577,000	1,989,292,160	2,281,071,600	2,145,050,000	947,205,000	385,068,760	14	
2,060,415,000	2,065,155,000	2,222,104,020	2,107,362,600	892,686,000	377,392,240	15	
2,261,793,000	2,137,516,960	2,173,801,500	2,069,357,400	974,529,520	371,973,520	16	
2,490,151,120	2,184,727,240	2,116,305,000	2,194,980,760	851,210,680	364,297,000	17	
2,562,792,000	2,228,019,880	2,060,415,000	2,032,470,000	799,657,680	356,620,480	18	
2,669,265,760	2,291,009,000	2,036,941,200	1,981,714,000	627,947,640	350,926,320	19	
2,745,831,240	2,300,358,120	2,027,326,000	1,913,831,000	718,495,200	341,740,500	20	
2,896,580,000	2,329,574,120	2,151,688,120	1,895,904,500	687,965,200	338,241,140	21	
2,932,962,000	2,369,307,880	2,248,387,640	1,838,961,500	670,257,800	330,805,000	22	
2,932,962,000	2,419,182,380	2,409,559,500	1,752,611,640	632,581,000	330,805,000	23	
2,771,323,000	2,469,702,500	2,626,441,000	1,684,212,100	615,792,320	325,555,960	24	
2,735,623,500	2,553,016,480	2,757,830,000	1,663,399,000	598,464,400	321,619,180	25	
2,668,122,500	2,626,441,000	2,849,404,260	1,651,505,800	575,482,000	316,370,140	26	
2,590,498,220	2,680,945,240	2,712,673,160	1,798,576,040	561,802,000	312,433,360	27	
2,488,632,920	2,713,388,240	2,712,673,160	1,671,327,800	543,254,560	306,972,320	28	
2,421,074,220	2,585,371,580	2,860,338,500	1,630,692,700	530,337,560	303,560,960	29	
2,290,558,000	2,536,668,500	2,712,673,100	1,617,808,400	517,420,560	296,311,820	30	
2,193,352,520	2,661,479,440	...	1,601,538,440	...	287,357,000	31	
73,196,606,040	66,859,213,000	75,221,939,260	64,483,583,320	26,662,689,780	11,787,789,580		

Appendix

Daily discharges of Irrawaddy in Cubic

Year.	Days of the month.	January.	February.	March.	April.	May.	June.
1875.	1	283,945,640	252,196,000	173,440,440	334,304,360	482,828,000	521,554,000
	2	280,107,860	252,196,000	173,440,440	316,370,140	437,527,260	512,770,440
	3	276,696,500	236,157,060	176,827,000	301,428,860	416,412,360	454,361,600
	4	274,990,820	232,811,940	165,454,160	276,696,500	398,582,000	524,099,820
	5	273,285,140	225,703,560	158,907,920	266,036,000	419,636,800	555,560,000
	6	269,447,360	216,889,260	155,233,580	258,736,620	426,431,900	560,211,360
	7	267,741,680	210,293,740	155,233,580	274,373,000	465,634,400	574,746,860
	8	266,036,000	208,644,860	150,334,460	262,499,880	570,095,000	600,634,500
	9	262,499,880	208,644,860	148,701,420	257,064,060	779,605,000	615,904,000
	10	258,736,620	203,286,000	147,068,380	244,938,000	892,454,600	636,059,740
	11	255,391,500	199,988,240	147,068,380	237,829,620	936,651,520	658,059,040
	12	252,046,380	196,278,260	145,027,080	237,829,620	1,100,096,000	690,065,040
	13	250,373,820	192,980,500	145,027,080	236,157,060	1,003,308,000	797,075,500
	14	248,283,120	189,782,740	143,394,040	236,157,060	959,742,160	1,086,219,240
	15	246,610,560	182,675,000	141,761,000	234,484,500	889,862,880	1,480,906,600
	16	234,484,500	179,394,840	138,505,800	248,699,360	822,901,000	1,709,194,640
	17	252,196,000	174,064,580	145,227,000	289,257,980	772,348,000	1,820,771,000
	18	243,265,440	169,144,340	148,589,720	340,044,920	735,093,440	1,873,330,000
	19	239,920,320	169,144,340	162,881,280	365,481,720	718,495,200	1,944,990,840
	20	236,993,340	180,213,560	173,440,440	404,489,500	703,230,200	1,972,003,840
	21	234,484,500	184,023,440	184,023,440	434,795,100	814,546,000	2,090,902,000
	22	231,139,380	198,117,000	198,117,000	467,725,200	814,546,000	2,213,209,240
	23	229,466,820	198,117,000	212,209,320	498,153,000	862,598,400	2,281,659,880
	24	239,520,680	185,972,760	228,863,880	565,444,140	789,199,000	2,419,182,380
	25	241,269,000	181,034,920	241,269,000	600,634,500	772,348,000	2,479,325,380
	26	243,017,320	174,064,580	255,692,640	618,347,120	692,850,000	2,680,945,240
	27	243,017,320	169,144,340	266,619,640	568,915,600	677,585,000	2,745,831,240
	28	234,484,530	167,504,260	285,649,500	552,499,600	632,581,000	2,826,169,000
	29	246,951,040	...	317,674,760	534,471,000	577,670,800	2,944,604,240
	30	250,447,680	...	347,161,080	519,487,280	548,122,000	3,083,943,000
	31	252,196,000	...	355,147,000	...	534,471,000	...
Total,	...	7,819,046,720	5,538,467,980	6,087,990,460	10,983,351,300	21,647,452,920	45,354,289,660
1876.	1	264,172,440	169,144,340	184,023,440	201,657,120	263,123,000	514,162,740
	2	255,391,500	169,144,340	190,857,320	192,980,500	263,123,000	456,324,800
	3	253,718,940	167,094,240	182,675,000	205,376,680	274,373,000	511,954,500
	4	253,300,800	166,274,200	175,704,660	208,793,000	308,202,500	516,370,980
	5	252,046,380	173,440,440	167,094,240	212,209,320	311,810,980	422,043,000
	6	250,373,820	173,440,440	158,907,920	213,917,480	327,890,920	379,198,480
	7	243,265,440	181,906,840	151,967,500	232,090,320	331,659,000	356,620,480
	8	237,829,620	183,176,800	151,967,500	232,673,080	298,017,500	349,167,640
	9	234,484,500	187,441,000	148,701,420	341,523,960	287,357,000	379,800,500
	10	231,139,380	179,394,840	148,701,420	392,145,000	283,945,640	392,145,000
	11	229,466,820	175,704,660	173,440,440	426,431,900	273,285,140	408,439,740
	12	225,703,560	174,064,580	176,827,000	454,657,700	271,579,460	408,439,740
	13	223,072,560	169,144,340	194,700,680	465,634,400	271,579,460	408,439,740
	14	220,599,240	165,454,160	216,052,680	430,019,740	304,594,020	412,883,760
	15	216,889,260	163,814,080	219,469,000	383,262,520	335,417,080	434,795,100
	16	211,942,620	162,994,040	221,177,160	367,909,480	375,850,260	443,681,000
	17	210,293,740	162,174,000	228,863,880	341,740,500	400,539,260	740,041,160
	18	208,644,860	158,907,920	241,269,000	312,433,360	379,198,480	917,213,400
	19	206,583,760	148,701,420	248,699,360	298,017,500	375,586,000	1,127,033,240
	20	203,286,000	145,027,080	250,447,680	283,945,640	364,297,000	1,211,102,920
	21	199,988,240	143,394,040	234,484,500	276,696,500	356,620,480	1,239,858,080
	22	196,278,260	140,133,400	225,703,560	262,499,880	353,008,000	1,335,584,000
	23	192,980,500	136,471,300	220,599,240	255,391,500	375,850,260	1,365,566,280
	24	191,331,620	134,843,700	216,889,260	249,955,680	358,878,280	1,512,652,400
	25	185,972,760	131,588,500	213,591,500	259,626,360	358,878,280	1,667,513,000
	26	184,323,880	128,333,300	204,934,880	296,926,000	356,620,480	1,811,858,920
	27	182,675,000	145,227,000	198,339,360	304,594,020	375,850,260	1,891,200,060
	28	179,394,840	155,735,500	196,278,260	283,945,640	388,194,760	2,016,305,160
	29	174,064,580	173,440,440	212,209,320	273,285,140	398,070,360	2,090,902,000
	30	172,424,500	...	212,209,320	252,046,380	447,862,600	2,166,498,760
	31	170,784,420	...	204,934,880	...	484,351,500	...
Total.	...	6,662,423,840	4,665,610,940	6,171,721,380	9,003,367,300	10,555,613,960	27,887,805,580

V.—continued.

Metres at **Saiktha** *or* **Myanoung.**

July.	August.	September.	October.	November.	December.	Days of the month.	Year.
3,143,501,160	2,723,740,420	3,318,986,400	1,386,594,370	1,111,449,680	431,896,620	1	
3,174,847,560	2,928,800,870	3,431,355,090	1,382,209,910	1,047,919,280	422,043,000	2	
3,233,823,320	3,070,006,270	3,569,824,790	1,503,053,210	984,079,000	414,066,260	3	
3,261,134,680	3,147,324,410	3,665,763,520	1,665,006,810	956,792,240	406,558,740	4	
3,269,669,480	3,147,324,410	3,767,298,530	1,722,688,850	910,330,500	398,582,000	5	
3,290,153,000	3,198,843,340	3,866,161,570	1,589,846,680	857,397,000	392,745,280	6	
3,296,980,840	3,215,414,800	3,955,806,360	1,705,782,040	822,901,000	385,068,760	7	
3,157,866,000	3,302,414,940	3,983,265,540	1,748,237,010	789,199,000	379,198,480	8	
3,144,498,800	3,389,415,090	3,983,265,540	1,752,324,690	748,582,160	371,973,520	9	
3,144,498,800	3,529,926,740	3,784,263,860	1,627,885,570	718,495,200	360,684,520	10	
3,290,153,000	3,628,498,390	3,709,472,470	1,627,885,570	692,850,000	353,008,000	11	
3,290,153,000	3,855,473,670	3,547,869,100	1,627,885,570	656,895,640	353,008,000	12	
3,332,827,000	4,083,949,200	3,380,954,000	1,756,412,370	637,212,360	349,176,640	13	
3,379,513,000	4,281,944,860	3,173,450,240	1,756,412,370	618,108,000	338,241,140	14	
3,411,434,580	4,538,811,640	2,979,495,976	1,613,041,130	603,635,000	338,241,140	15	
3,426,456,500	4,568,008,910	2,820,537,550	1,566,652,230	584,784,400	334,304,360	16	
3,221,366,200	4,608,024,970	2,731,843,950	1,685,891,680	566,179,600	332,554,680	17	1875.
3,157,866,000	4,353,720,600	2,518,785,340	1,791,157,650	557,424,400	329,055,320	18	
2,953,884,000	4,243,593,000	3,336,078,580	1,820,771,000	565,444,140	323,368,860	19	
2,888,024,580	4,103,430,600	2,208,653,820	1,592,904,020	523,620,720	316,370,140	20	
2,855,029,500	3,869,769,380	2,056,476,820	1,743,401,000	517,420,560	310,683,680	21	
2,840,247,240	3,699,046,450	1,985,411,049	1,613,844,000	508,637,000	301,423,860	22	
2,792,615,490	3,491,746,930	1,839,058,300	1,747,488,040	504,503,560	298,017,500	23	
2,792,615,490	3,304,783,860	1,668,123,880	1,747,488,040	486,754,400	294,606,140	24	
2,751,553,640	3,157,048,320	1,660,498,120	1,609,213,480	482,828,000	287,357,000	25	
2,725,274,060	2,972,178,260	1,574,074,450	1,568,919,520	472,521,200	283,945,640	26	
2,668,388,740	2,866,071,440	1,499,789,580	1,517,113,000	466,631,600	283,945,640	27	
2,589,567,700	2,866,071,440	1,437,454,105	1,415,592,160	454,361,600	276,696,500	28	
2,811,998,010	3,040,551,360	1,408,516,670	1,617,892,000	447,981,200	274,990,820	29	
2,440,052,310	3,070,006,270	1,386,594,370	1,252,857,080	439,404,140	269,447,360	30	
2,591,346,080	3,250,629,140	...	1,182,709,000	...	264,172,440	31	
94,027,283,760	109,506,569,980	84,249,129,570	49,939,140,050	19,734,342,580	10,575,437,040		
2,213,209,240	3,102,750,840	3,206,322,100	1,764,856,960	820,204,840	490,976,220	1	
2,217,766,360	3,149,770,440	3,065,139,200	1,786,314,920	776,201,920	462,214,400	2	
2,083,888,800	3,162,309,000	2,908,967,800	1,663,399,000	742,801,280	456,324,800	3	
2,064,886,200	3,020,473,400	2,662,722,420	1,630,692,700	715,442,200	439,404,140	4	
2,055,943,800	3,000,450,800	2,406,334,140	1,611,132,240	692,850,000	423,919,880	5	
2,225,741,320	2,968,106,600	2,178,401,740	1,600,579,060	764,811,920	408,435,620	6	
2,354,115,560	2,961,945,800	2,036,941,200	1,589,066,500	834,811,780	390,487,480	7	
2,536,838,760	2,961,945,800	1,954,564,000	1,583,310,220	869,880,400	375,586,000	8	
2,631,631,880	3,102,750,840	1,849,506,500	1,731,139,880	800,657,680	364,297,000	9	
2,686,136,120	3,116,856,720	1,777,158,360	1,895,404,780	785,836,720	360,684,520	10	
2,728,960,880	3,136,225,280	1,688,176,500	2,020,627,240	761,428,560	350,926,320	11	
2,763,297,120	3,156,039,720	1,638,621,500	1,900,122,500	726,743,280	338,241,140	12	
2,817,968,320	3,168,578,280	1,619,790,600	1,743,406,620	684,912,200	334,304,360	13	
2,883,573,760	3,195,222,720	1,747,488,040	1,634,657,100	644,738,320	327,305,640	14	
2,975,165,120	3,208,218,920	1,764,857,960	1,537,259,980	614,634,480	321,619,180	15	
3,051,029,280	3,208,218,920	1,773,032,040	1,466,226,280	725,982,080	314,620,460	16	
3,135,664,560	3,065,139,200	1,642,585,900	1,435,612,840	889,541,800	305,266,640	17	1876.
3,261,134,680	2,985,048,800	1,585,228,980	1,419,176,080	710,557,400	301,428,860	18	
3,353,310,520	2,985,048,800	1,524,788,040	1,520,855,000	589,162,000	298,870,340	19	
3,415,190,060	2,985,048,800	1,435,612,840	1,522,781,080	543,254,560	294,606,140	20	
3,477,155,480	3,215,046,760	1,351,977,580	1,411,112,260	527,754,160	287,357,000	21	
3,488,421,920	3,233,823,320	1,292,613,040	1,396,776,580	514,837,160	285,651,320	22	
3,495,932,880	3,257,720,760	1,221,006,760	1,355,561,500	493,134,800	280,107,860	23	
3,336,700,000	3,296,980,840	1,179,378,760	1,321,133,620	482,828,000	274,990,820	24	
3,312,910,520	3,368,673,160	1,137,878,060	1,271,006,540	476,447,600	267,741,680	25	
3,252,521,840	3,422,701,020	1,105,843,660	1,234,327,720	476,447,600	266,036,000	26	
3,174,575,000	3,452,744,860	1,193,342,380	1,157,899,560	470,558,000	260,409,180	27	
3,087,688,200	3,480,910,960	1,258,726,740	1,077,147,360	458,288,000	255,391,500	28	
3,012,722,400	3,512,832,540	2,323,475,260	974,491,760	454,361,600	249,955,680	29	
2,949,624,200	3,527,854,460	1,611,380,760	925,151,880	486,559,740	246,610,560	30	
2,926,521,200	3,344,019,840	...	860,220,120	...	243,265,440	31	
88,970,275,980	98,754,458,200	53,141,862,860	46,041,450,680	19,535,670,080	10,277,036,180		

Appendix

Detail discharges of Irrawaddy in Cubic

Year.	Days of the month.	January.	February.	March.	April.	May.	June.
1877.	1	239,502,180	160,540,960	128,333,300	185,148,320	217,713,700	676,622,520
	2	234,484,500	155,233,580	121,416,000	220,323,080	214,415,940	728,998,960
	3	231,139,380	153,600,540	129,759,520	276,177,240	214,415,940	792,882,580
	4	225,703,560	151,967,500	116,545,680	312,713,100	206,583,760	811,750,720
	5	225,867,280	148,701,420	112,892,940	323,673,080	202,461,560	974,529,520
	6	222,248,120	145,027,080	112,892,940	323,673,080	197,102,700	866,572,140
	7	218,538,140	141,761,000	117,247,560	306,119,480	197,102,700	753,720,720
	8	215,240,380	140,133,400	119,329,160	306,119,480	197,102,700	675,142,600
	9	211,942,620	138,505,800	120,994,440	323,673,080	195,980,500	574,387,600
	10	208,232,640	134,843,700	124,325,000	324,612,600	192,980,500	518,453,920
	11	204,934,880	141,882,680	124,325,000	308,934,000	185,972,760	511,737,080
	12	201,637,120	145,227,000	119,792,560	308,934,000	179,394,840	509,670,360
	13	199,988,240	152,372,780	116,545,680	308,934,000	175,704,660	549,745,800
	14	196,278,260	164,562,640	115,733,960	304,413,800	173,244,540	556,722,840
	15	192,980,500	169,630,560	120,994,440	291,621,200	169,964,380	516,387,200
	16	189,682,740	176,827,000	120,994,440	276,696,500	169,964,380	579,979,640
	17	185,972,760	181,906,840	121,827,080	265,916,896	178,520,280	656,778,800
	18	184,323,880	185,716,720	123,492,360	249,190,816	187,441,000	837,607,060
	19	181,034,920	187,441,000	125,161,080	236,157,060	195,484,080	1,075,807,320
	20	179,394,840	190,857,320	127,669,320	228,212,400	198,870,640	1,243,241,040
	21	175,704,660	190,857,320	128,923,440	224,867,280	200,563,920	1,369,948,920
	22	172,424,500	182,675,000	121,416,000	221,423,680	194,565,580	1,436,089,000
	23	170,784,420	177,344,740	112,081,220	218,950,360	201,410,360	1,574,786,240
	24	170,784,420	165,454,160	131,431,680	216,889,260	214,956,800	1,719,900,520
	25	176,827,000	155,233,580	146,908,360	230,342,000	237,679,200	1,766,901,480
	26	178,520,280	148,701,420	160,779,580	252,196,000	254,511,600	1,921,684,280
	27	181,906,840	141,761,000	173,440,440	270,553,360	244,776,000	1,762,839,440
	28	184,023,440	134,843,700	189,149,160	259,572,900	271,775,600	1,731,133,260
	29	175,704,660	...	198,117,000	244,938,000	379,482,500	1,867,022,920
	30	173,424,500	...	198,117,000	234,484,500	490,970,440	1,928,783,040
	31	170,784,420	...	185,972,760	...	599,075,300	...
Total ...		5,978,016,080	4,463,610,440	4,166,609,100	8,055,460,540	7,140,188,860	31,489,827,520

V.—continued.

Metres at **Saiktha** *or* **Myanoung.**

July.	August.	September.	October.	November.	December.	Days of the Month.	Year.
1,790,454,500	2,932,962,000	3,987,708,020	3,196,296,700	1,285,698,960	553,594,000	1	
1,773,067,240	3,017,368,240	3,884,511,710	3,171,233,200	1,382,609,680	541,187,840	2	
1,944,829,800	3,083,943,000	3,732,931,030	3,157,866,000	1,269,278,020	529,304,200	3	
2,001,177,880	3,152,905,080	3,529,623,560	3,147,840,600	1,242,857,080	517,420,560	4	
2,187,005,800	3,237,237,240	3,247,258,880	3,315,757,400	1,392,557,420	506,570,280	5	
2,279,320,600	3,496,304,520	2,971,187,000	3,171,233,200	1,289,156,000	499,853,440	6	
2,366,970,600	3,772,642,480	2,681,622,700	3,315,757,400	1,432,354,200	539,861,660	7	
2,397,530,900	4,059,541,040	2,380,539,000	3,332,827,000	1,283,970,440	561,374,200	8	
2,224,404,140	4,334,273,650	2,190,402,000	3,365,259,240	1,235,160,280	575,909,700	9	
2,135,307,600	4,574,986,080	1,880,087,000	3,403,923,620	1,219,341,640	587,808,120	10	
2 091,154,500	4,731,689,300	1,762,839,440	3,441,478,420	1,184,374,120	538,604,440	11	
2,047,001,400	4,747,645,990	1,758,748,320	3,465,889,040	1,184,374,120	517,420,560	12	
1,991,488,000	4,485,300,640	2,058,715,480	3,505,321,580	1,285,851,120	496,753,360	13	
1,991,488,000	4,458,869,200	2,239,412,680	3,325,720,240	1,289,351,040	477,920,000	14	
2,144,176,240	4,436,213,680	2,386,705,160	3,259,841,680	1,161,895,000	462,214,400	15	
2,171,055,880	4,320,348,600	2,494,962,560	3,182,929,500	1,084,220,440	452,398,400	16	1877.
2,190,423,640	4,210,241,000	2,622,705,120	3,074,321,000	1,003,308,000	438,465,700	17	
2,064,886,200	4,186,860,600	2,728,960,880	2,920,360,400	926,563,440	428,142,860	18	
2,018,638,000	4,815,461,910	2,820,701,880	2,755,873,800	843,796,240	424,858,320	19	
1,939,360,000	4,990,985,480	2,896,580,000	2,549,485,100	804,701,920	411,250,940	20	
1,849,506,500	4,226,907,000	2,994,083,760	2,380,539,000	760,143,920	405,620,300	21	
1,813,978,440	3,743,357,050	3,071,404,440	2,173,881,500	726,743,280	400,458,880	22	
1,948,232,400	3,457,124,140	3,152,905,080	1,970,854,000	697,734,800	396,357,760	23	
2,123,088,520	3,376,337,630	3,221,874,600	1,816,817,000	672,700,200	388,681,240	24	
2,225,741,320	3,371,721,260	3,283,325,160	2,063,155,000	649,369,680	382,359,400	25	
2,271,142,120	3,553,396,180	3,336,240,920	2,247,387,640	632,581,000	375,586,000	26	
2,356,452,840	3,676,451,412	3,372,087,080	1,832,634,500	613,476,640	367,006 360	27	
2,474,513,940	3,876,849,460	3,379,513,000	1,671,327,800	598,464,400	360,784,420	28	
2,572,927,520	4,007,673,700	3,231,385,600	1,485,707,560	580,954,000	354,814,240	29	
2,693,922,440	4,096,153,280	3,216,347,500	1,340,329,840	567,274,000	349.176,640	30	
2,802,933,740	4,172,428,780	...	1,294,341,560	...	346,114,700	31	
66,882,182,700	122,604,179,620	86,515,369,560	84,336,110,520	30,300,861,080	14,187,872,920	Total	

Appendix

Daily discharge of Irrawaddy in Cubic

Year.	Days of the month.	January.	February.	March.	April.	May.	June.
1878.	1	339,990,820	243,265,440	246,610,560	299,632,360	312,433,360	355,717,360
	2	335,179,200	239,920,320	239,920,320	282,239,960	305,693,060	382,763,180
	3	330,805,000	234,484,500	249,573,520	271,579,460	297,164,660	405,501,060
	4	326,430,800	231,975,660	273,175,840	263,336,160	295,032,560	421,727,600
	5	322,494,020	228,212,400	323,673,080	256,227,780	292,474,040	400,458,880
	6	318,119,820	223,072,560	361,253,880	252,882,660	287,357,000	386,875,000
	7	311,558,520	219,774,800	363,130,920	251,210,100	283,945,640	367,909,480
	8	309,808,840	217,713,700	335,179,200	275,275,120	283,945,640	355,717,360
	9	307,825,160	213,591,500	322,494,020	310,006,740	293,768,580	341,740,500
	10	321,794,040	220,323,080	318,119,820	342,463,480	282,239,960	327,305,640
	11	337,765,880	220,323,080	338,705,400	353,267,960	275,943,660	317,244,980
	12	357,026,040	221,177,160	345,282,040	338,241,140	272,432,300	369,431,120
	13	367,456,000	208,644,860	329,930,160	363,132,900	271,579,460	369,431,120
	14	350,926,320	204,934,880	316,470,140	397,082,800	298,730,240	430,613,500
	15	334,304,360	199,988,240	299,723,180	437,408,600	323,673,080	541,024,500
	16	320,744,340	195,453,820	289,915,520	440,544,800	340,584,440	603,077,620
	17	308,934,000	194,331,620	273,285,140	467,725,200	340,584,440	641,556,760
	18	298,017,500	188,033,860	264,172,440	431,427,400	343,403,000	668,300,960
	19	290,759,360	185,972,760	255,391,500	420,166,120	343,403,000	614,634,480
	20	284,798,480	192,992,520	248,283,120	419,227,680	700,306,960	611,160,960
	21	279,255,020	198,117,000	243,265,440	416,412,360	579,859,600	659,339,280
	22	274,147,980	215,198,600	236,993,340	408,435,620	463,686,800	599,558,800
	23	269,447,360	247,825,200	231,139,380	395,454,640	384,617,200	593,539,600
	24	265,008,720	280,236,780	224,867,280	383,262,520	367,909,480	647,177,000
	25	260,827,320	291,513,280	223,072,560	380,101,600	364,297,000	653,478,080
	26	258,736,620	276,696,500	233,838,640	401,526,820	399,057,920	865,511,200
	27	256,227,780	266,036,000	242,143,160	380,101,600	362,490,760	1,067,938,120
	28	255,391,500	254,555,220	253,070,160	365,200,120	362,039,200	1,189,471,020
	29	255,391,500	...	265,745,480	342,615,340	378,812,940	1,301,600,760
	30	252,882,660	...	284,747,380	326,430,800	379,800,500	1,405,218,180
	31	249,119,400	...	298,730,240	...	359,778,280	...
Total	...	9,351,174,360	6,311,425,340	8,731,902,860	10,672,619,840	10,847,044,760	17,895,024,000
1879.	1	367,909,480	248,283,120	201,637,120	312,433,360	187,441,000	410,312,500
	2	364,297,000	248,283,120	199,988,240	287,357,000	187,441,000	408,874,840
	3	356,620,480	244,938,000	197,927,140	266,036,000	187,441,000	402,335,760
	4	349,176,640	244,938,000	196,278,260	248,283,120	187,441,000	541,020,500
	5	345,239,860	241,592,880	194,629,380	237,829,620	222,885,320	797,075,500
	6	341,740,500	241,592,880	192,980,500	230,721,240	270,553,360	1,100,096,000
	7	338,241,140	437,829,620	191,331,620	220,599,240	296,926,000	1,403,409,500
	8	334,304,360	437,829,620	189,682,740	218,950,360	300,534,480	1,600,787,320
	9	327,305,640	234,484,500	188,033,860	215,240,380	280,107,860	1,768,945,000
	10	323,368,860	234,484,500	185,972,760	213,591,500	262,499,880	1,944,990,840
	11	319,869,500	231,139,380	184,323,880	211,530,400	253,718,940	2,063,155,000
	12	319,869,500	231,139,380	182,675,000	222,885,320	243,265,440	2,204,095,000
	13	316,370,140	227,376,120	182,675,000	226,728,680	239,920,320	2,300,358,120
	14	312,433,360	227,376,120	182,675,000	218,950,360	239,920,320	2,389,110,880
	15	305,266,640	224,031,000	182,675,000	216,889,260	252,196,000	2,449,253,880
	16	301,428,860	224,031,000	194,700,680	213,591,500	257,440,960	2,490,151,120
	17	298,017,500	218,599,240	198,117,000	211,530,400	257,440,960	2,490,151,120
	18	294,606,140	218,599,240	201,533,320	220,325,080	264,871,320	2,359,334,400
	19	290,768,360	216,889,260	205,376,680	208,282,640	255,391,500	2,329,689,400
	20	287,357,000	216,889,260	207,084,840	206,583,760	304,594,020	2,320,203,000
	21	284,945,640	213,591,500	208,793,000	204,934,880	355,147,000	2,469,702,500
	22	280,107,860	213,591,500	208,793,000	204,934,880	390,169,880	2,541,816,520
	23	273,285,140	210,293,740	212,209,320	213,917,480	404,489,500	2,636,822,760
	24	273,285,140	210,293,740	259,626,360	220,325,080	383,262,520	2,745,831,240
	25	269,447,360	206,583,760	277,981,480	211,530,400	381,004,720	2,849,404,260
	26	262,499,880	206,583,760	335,417,080	201,224,900	412,883,760	2,932,962,000
	27	262,499,880	203,286,000	396,095,240	190,919,400	444,726,400	3,005,726,000
	28	258,736,620	203,286,000	217,546,000	182,675,000	447,980,040	3,057,298,560
	29	258,736,620	...	386,875,000	178,912,660	488,767,980	3,110,587,440
	30	255,391,500	...	367,909,480	178,912,660	458,288,000	3,149,770,440
	31	252,046,380	...	341,740,500	...	441,750,240	...
Total	...	9,425,172,980	6,717,836,240	7,273,284,480	6,596,626,560	9,460,500,720	62,273,271,400

V.—concluded.

Metres at **Saiktha** *or* **Myanoung.**

July.	August.	September.	October.	November.	December.	Days of the Month.	Years.
1,539,152,760	3,383,268,480	2,701,708,760	3,332,827,000	1,533,422,460	632,581,000	1	1878.
1,727,058,200	3,445,233,900	2,760,563,560	3,346,482,680	1,500,550,440	618,108,000	2	
1,775,075,560	3,480,910,960	2,815,234,760	3,346,482,680	1,362,729,340	636,653,200	3	
1,871,227,640	3,516,588,020	2,768,080,850	3,012,772,400	1,282,241,920	627,350,800	4	
1,944,990,840	3,524,098,980	2,957,701,760	2,955,785,000	1,203,523,000	613,670,800	5	
2,022,788,280	3,524,098,980	3,017,368,240	2,843,013,000	1,141,081,500	597,802,000	6	
2,099,781,040	3,354,999,600	3,071,404,440	2,691,072,840	1,094,631,620	545,321,280	7	
2,187,005,800	3,325,720,240	3,113,722,080	2,493,546,280	1,054,841,720	532,404,280	8	
2,268,804,840	3,279,971,240	3,123,126,000	2,406,334,140	1,035,612,720	521,554,000	9	
2,347,103,720	3,234,727,400	3,368,673,160	2,359,334,400	1,035,612,720	512,770,440	10	
2,467,296,780	3,189,613,100	3,189,613,100	2,329,689,400	1,022,537,000	504,503,560	11	
2,544,305,400	3,174,575,000	3,174,575,000	2,479,325,380	1,106,626,240	491,171,600	12	
2,626,441,000	3,106,068,100	3,106,068,100	2,599,060,760	1,120,503,000	482,828,000	13	
2,718,579,120	3,048,197,000	3,048,197,000	2,425,987,580	1,127,033,240	478,901,600	14	
2,771,497,800	3,045,116,600	3,045,116,600	2,808,400,860	1,147,440,240	474,484,400	15	
2,805,667,300	3,233,823,320	3,233,823,320	3,355,017,480	1,047,919,280	470,558,000	16	
2,852,137,820	3,300,394,760	3,372,087,080	3,426,456,500	1,134,379,760	462,214,400	17	
2,879,473,420	3,355,017,480	3,221,360,200	3,276,311,320	1,154,786,760	441,750,240	18	
2,911,132,800	3,361,945,320	3,361,945,320	3,213,005,700	1,225,480,500	437,527,260	19	
2,930,051,440	3,216,347,500	3,216,347,500	3,157,866,000	1,127,466,880	430,019,740	20	
2,947,514,800	3,132,802,500	3,129,460,700	3,032,795,000	1,074,070,720	425,796,760	21	
2,957,701,760	3,020,473,400	3,020,473,400	2,884,593,200	1,016,383,720	422,043,000	22	
2,963,522,880	2,920,360,400	2,920,360,400	2,712,673,160	952,104,840	415,943,140	23	
2,980,986,240	2,863,086,200	3,208,218,920	2,536,668,500	875,041,500	410,312,500	24	
3,002,815,440	2,834,410,200	3,000,450,800	2,359,334,400	817,508,680	402,335,760	25	
3,036,286,880	2,815,770,800	2,955,785,000	2,183,001,980	767,209,440	394,551,520	26	
3,071,404,440	2,785,661,000	2,952,704,600	1,986,058,000	735,093,440	390,487,480	27	
3,126,260,640	2,720,773,280	3,102,750,840	1,843,179,500	703,230,200	386,875,000	28	
3,177,982,200	2,657,322,340	3,159,174,360	1,705,025,200	677,585,000	381,004,720	29	
3,244,065,080	2,605,878,140	3,254,306,840	1,596,741,540	656,895,640	375,586,000	30	
3,303,808,680	2,571,273,320	...	1,533,422,460	...	353,779,760	31	
81,101,920,600	97,028,527,560	92,370,402,690	82,232,264,340	31,733,543,520	14,870,890,240	Total	
3,174,847,560	4,369,745,500	4,443,547,000	2,826,169,000	2,125,247,400	512,770,400	1	1879.
3,188,953,440	4,152,315,280	4,222,769,280	2,536,668,500	2,022,982,000	505,536,920	2	
3,218,460,680	4,079,679,600	4,129,770,000	2,202,553,000	1,995,832,000	579,979,640	3	
3,247,479,000	3,944,074,800	4,059,590,000	2,107,362,600	1,923,070,000	486,754,400	4	
3,261,134,680	3,734,587,840	3,976,720,400	2,041,412,400	1,773,067,240	480,864,800	5	
3,261,134,680	3,549,950,800	3,826,695,160	1,958,908,000	1,589,066,500	472,521,200	6	
3,116,093,500	3,382,449,000	3,714,369,160	1,950,220,000	1,393,192,660	460,251,200	7	
3,102,726,300	3,290,951,000	3,467,106,200	1,913,831,000	1,238,490,520	454,361,600	8	
3,087,688,200	3,228,043,800	3,228,043,000	1,739,315,500	1,114,653,120	452,398,400	9	
3,233,823,320	3,379,513,000	3,032,795,000	1,663,399,000	1,028,690,280	441,750,240	10	
3,233,823,320	3,221,360,200	2,831,542,600	1,605,375,960	959,742,160	439,404,140	11	
3,096,042,700	3,157,866,000	2,577,681,620	1,557,406,960	910,330,500	430,019,740	12	
3,045,116,600	3,065,139,200	2,577,681,620	1,533,422,460	869,395,260	422,043,000	13	
3,032,795,000	2,981,968,400	2,860,338,500	1,524,788,040	834,359,680	449,953,400	14	
3,020,473,400	2,948,084,000	3,030,465,760	1,524,788,040	800,657,680	410,312,500	15	
3,174,847,560	2,903,232,600	3,056,514,900	1,634,763,140	761,428,560	408,435,620	16	
3,261,134,680	3,062,000,520	3,276,497,320	1,508,599,560	729,312,560	402,235,760	17	
3,346,482,680	3,110,587,440	3,361,845,320	1,454,166,440	703,230,200	398,582,000	18	
3,426,456,500	3,182,684,160	3,486,544,180	1,347,528,340	682,469,800	398,582,000	19	
3,458,378,080	3,261,134,680	3,520,343,500	1,377,961,000	667,204,800	394,551,520	20	
3,535,365,420	3,339,654,840	3,552,265,080	1,504,249,100	647,054,000	390,487,480	21	
3,607,614,520	3,441,478,420	3,659,703,520	1,609,454,680	627,949,640	390,487,480	22	
3,640,951,480	3,520,343,500	3,437,807,500	1,717,857,000	613,476,640	383,262,520	23	
3,728,461,000	3,624,283,000	3,413,558,320	1,768,945,000	598,464,400	375,586,000	24	
3,835,325,280	3,745,129,480	3,382,449,000	1,777,119,080	584,784,400	371,973,520	25	
3,921,486,440	3,863,269,440	3,116,093,500	1,811,858,920	571,104,400	364,297,000	26	
4,026,214,000	3,979,703,440	3,074,321,000	1,696,105,300	557,425,400	356,620,480	27	
4,167,492,040	4,136,096,920	2,903,232,600	1,655,470,200	543,254,560	349,176,640	28	
4,243,363,580	4,295,944,000	2,771,323,000	1,855,459,940	530,337,560	345,239,860	29	
4,346,129,020	4,346,129,020	2,668,122,500	2,016,305,160	521,554,000	341,740,500	30	
4,369,745,500	4,369,745,500	...	2,300,358,120	...	338,241,140	31	
107,410,040,160	110,667,145,380	100,659,736,540	55,722,121,440	29,917,827,920	13,008,421,100	Total	

Appendix VI.

Measurements of River Surface Slope at **Saiktha** *and* **Talokmoh.**

March 1877 — SAIKTHA.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″	
1	2 1¼	0 1⅜	0 1	
2	2 0	0 1⅜	1	1·37
3	1 11	0 1¾	1	
4	1 10½	0 1⅝	1	
5	1 10	0 1¾	1	
6	1 9¼	0 1¼	1	
7	1 9	0 1½	1	
8	1 8¾	0 1½	1	
9	1 8	0 1½	1	
10	1 7½	0 1½	1	
11	1 7¼	0 1¾	1	
12	1 7½	0 1½	1	1·30
13	1 8½	0 1½	1	
14	1 8¼	0 1½	1	
15	1 8½	0 1½	1	
16	1 8¼	0 1¾	1	
17	1 8¾	0 1¾	1½	1·35
18	1 8	0 1¾	1	
19	1 7½	0 1¾	1¼	
20	1 7	0 1¾	1	
21	1 6¾	0 1¾	1	1·406
22	1 7¾	0 1¾	1	
23	1 11	0 1½	1	1·312
24	2 3½	0 1¾	1	
25	2 9	0 2	1	1·437
26	3 0	0 2	1	
27	3 3	0 2¼	1¼	
28	3 6	0 2½	1¼	
29	3 7½	0 2½	1¼	1·75
30	3 6	0 2½	1	
31	3 4	0 2½	1	1·75

March 1877 — TALOKMOH.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″		′ ″	
1	2 3¾		0 ½	
2	2 2½			
3	2 1½			
4	2 0¼			
5	2 0½			·50
6	1 11¾			
7	1 11½			
8	1 11½			
9	1 10½			
10	1 9¾			
11	1 9½			·62
12	1 9½			
13	1 10¼			
14	1 10¾			
15	1 10¾			
16	1 11¼			
17	1 11¼			·57
18	1 10¼			
19	1 9¾			
20	1 9½			
21	1 9½			0·50
22	1 9¾			0·50
23	2 0¾			
24	2 4¾			
25	2 8½		1	
26	3 0		⅓	0·69
27	3 3		½	
28	3 6		½	
29	3 7½		½	0·50
30	3 6		½	
31	3 4		¼	0·50

April 1877 — SAIKTHA.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″	
1	3 7	0 1	0 ¾	
2	4 4	1		0·87
3	5 1¾	1¼		
4	5 11¾	1¼		
5	5 11¾	1¼	1	1·041
6	5 10¾	1¼	1	
7	5 9¾	1¼	1	1·12
8	5 10¾	1¼	1	
9	5 11¾	1¼	1	
10	5 10¾	1¼	1	
11	5 10	1¼	1	
12	5 9¾	1¼	1	
13	5 9¾	1¼	1	
14	5 8¼	1¼	1	
15	5 4¾	1¼	1	
16	5 1	1	1	1·10
17	4 9¼	1¼	1¾	
18	4 6	1	1	
19	4 4	1	1	
20	4 3	1	1	
21	4 2½	1	1	
22	4 2	1	1	
23	4 1	1	1	1·017
24	4 2	1	1	
25	4 5	1	1	
26	4 10	1	1	
27	4 11½	1	1	1·00
28	4 10	1	1	
29	4 7	1	1	
30	4 4	1	1	1·00

April 1877 — TALOKMOH.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″		′ ″	
1	3 5½		0 ½	0·50
2	4 2½			0·50
3	5 3½			0·50
4	6 ½			
5	6 ½			0·50
6	5 11½			
7	5 10½			0·50
8	5 11½			
9	5 ½			
10	5 11½			
11	5 10½			
12	5 10½			
13	5 10½			
14	5 9½			
15	5 6			
16	5 2			0·50
17	4 9½			
18	4 7			
19	4 5½			0·50
20	4 4½			
21	4 4			
22	4 3½			
23	4 2½			0·50
24	4 3½			
25	4 6½			0·50
26	4 11½			
27	5 1½			0·50
28	4 11			
29	4 8			
30	4 5			

May 1877 — SAIKTHA.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″	
1	4 1	0 1	0 ⅜	
2	4 ¼	1		0·87
3	3 11½	1		
4	3 9½	1		
5	3 8½	1		
6	3 7¾	1		
7	3 7½	1		
8	3 7½	1		
9	3 7½	1		
10	3 6½	1		0·87
11	3 5	1		
12	3 3¾	1		
13	3 3¼	1		
14	3 2¼	1		
15	3 1½	1		
16	3 1	1		
17	3 3	1		
18	3 5	1		
19	3 6	1¼		
20	3 6¾	1¼		
21	3 7	1¼		
22	3 7½	1¼		
23	3 8¼	1¼		
24	3 9½	1½		0·968
25	4 3½	1¼	1	
26	4 7½	1½	1	
27	4 9½	1¼	1	1·12
28	5 1¼	1½	1	1·12
29	7 0	1¾	1½	1·62
30	9 0	2	2	
31	9 7	2	2	2·00

May 1877 — TALOKMOH.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″	
1	4 1½		0 ½	
2	4 1½			
3	4 1			
4	3 10½			0·50
5	3 9¾			
6	3 8			
7	3 7¾			
8	3 7¾			
9	3 7¾	0	⅜	
10	3 6¾			
11	3 6¼			
12	3 4			
13	3 3½			
14	3 2½			
15	3 1½			
16	3 1			0·60
17	3 3¼			
18	3 5¼			
19	3 6¾			
20	3 7			
21	3 7¼			
22	3 7½			
23	3 8½			
24	3 9½			0·65
25	4 3			
26	4 6¾			
27	4 9			0·65
28	5 ⅜			0·77
29	6 10¾			0·77
30	9 ⅞	1¼		1·00
31	9 7½	1¼		1·00

June 1877 — SAIKTHA.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″	
1	11 9¼	0 2½	0 2¼	2·37
2	12 1¾	2½	2¼	
3	12 9	2½	2¼	2·37
4	13 3½	2½	2¼	2·37
5	14 5¾	2½	2¼	2·37
6	13 9¾	2¼	2¼	2·25
7	12 9¾	2¼	2¼	2·25
8	11 4¾	2¼	2¼	2·25
9	9 9¾	2¼	2	2·12
10				
11				
12	9 3¾	0 2	0 1	
13	9 5¼	2	2	2·00
14	9 4¾	2¼	2	2·12
15	9 5	2¾	2¼	2·50
16	10 ¼	2¾	2½	2·62
17	11 9½	2¾	2½	
18	14 0	2¾	3	2·87
19	16 6¾	2¾	3	2·87
20	18 1½	3	3½	3·25
21	19 ½	3½	3½	3·50
22	20 2½	3½	4	3·75
23	21 2	4	4	4·00
24	22 4	4	4	4·00
25	23 0	4	4	4·00
26	24 3¾	4¼	4	4·12
27	23 7¼	4½	4¾	4·50
28	23 8¼	4¼	4¼	
29	23 10½	4½	4½	4·37
30	24 5	4	4½	4·25

June 1877 — TALOKMOH.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″	
1	11 9½	0 0¾	0 1¼	
2	12 2¾	¾	1¼	
3	12 10½	1	1¼	
4	13 5¼	1	1¼	
5	14 6¾	1	1¼	
6	13 11¼	1¼	1¼	1·28
7	12 11½	1¼	1¼	1·28
8	11 6¾	1¼	1	1·18
9	10 1½	1¼	1	1·18
10				
11				
12	9 6½	1¼	¾	1·06
13	9 7½	1½	1	1·28
14	9 7	1½	1¼	1·28
15	9 8	1¼	1¼	1·28
16	10 1	1¼	1¼	1·28
17	11 9½	1¼	1¼	1·28
18	13 10	1¼	1¼	1·28
19	16 6¾	1½	1½	1·28
20	18 3½	1½	1½	1·43
21	19 1	1½	1½	1·55
22	20 4¼	2	1¾	1·94
23	21 4	2	2	2·06
24	22 6	2	2	2·06
25	23 ¾	2	2¼	2·14
26	24 4	2	2¼	2·18
27	23 10½	2¼	2	
28	23 9½	2½	2	2·26
29	24 ½	2½	2	
30	24 6½	2¼	2½	2·24

Appendix VI.—continued.

Measurements of River Surface Slope at Saiktha *and* Talokmoh.

Date.	July 1877. SAIKTHA. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	July 1877. TALOKMOH. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	August 1877. SAIKTHA. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	August 1877. TALOKMOH. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″			′ ″	′ ″	′ ″			′ ″	′ ″	′ ″			′ ″	′ ″	′ ″	
1	24 ½	0 4½	0 4	4·25	1	24 3	0 2¼	0 2	2·18	1	32 9½	0 4½	0 5½	5·00	1	32 9½	0 5	0 2	3·60
2	23 11½	4½	4	4·25	2	23 11	3¼	4		2	33 3½	0 4¾	5		2	33 4¼	5	2	
3	24 9½	4	4	4·00	3	24 9	3½	2		3	33 8½	4¼	5	4·75	3	33 9¼	5¼	2	3·72
4	25 3	4	4	4·00	4	25 3	3¾	2¼	2·95	4	34 1	5½	5½		4	34 3	5¼	2	
5	27 0	4½	4	4·25	5	27 0	4¼	2¼		5	34 6½	7	5½	5·87	5	34 10	5¾	2	3·87
6	27 9½	4	4¾	4·312	6	27 9½	3¼	2¼	3·08	6	35 10	5	5½	5·25	6	35 10½	5¾	2	3·98
7	28 4½	4¾	4¼	4·50	7	28 5	3¾	2¼	3·09	7	37 10¾	6¼	5½	5·87	7	37 10½	6	2½	
8	28 3½	4½	4¼	4·37	8	28 4	4	2	3·09	8	38 8¾	6½	6½	6·37	8	38 7½	6½	2½	4·50
9	27 8	5	4	4·50	9	27 9	4	2		9	39 10¾	6¼	6¾	6·50	9	39 9	6½	2½	4·63
10	26 11¾	4¼	4¼		10	27 ¾	3¼	2	2·95	10	40 8¾	7¼	6¾	7·00	10	40 6½	7	2½	4·79
11	26 6	5	5		11	26 7¾	3¼	2		11	41 1	6½	8	7·25	11	41	11½	2½	7·21
12	26 5	5	5		12	26 6¾	3¼	2		12	41 ½	6	8	7·00	12	40 11½	10½	2½	6·70
13	26 0	4½	4	4·62	13	26 3¾	3¼	2		13	40 9½	6	8	7·00	13	40 9½	10½	1½	
14	25 11	4½	4	4·25	14	25 10¾	4¼	2	2·95	14	40 7	6	7¾		14	40 7	10½	1½	
15	26 5	4½	5		15	26 7	4	2	3·10	15	40 5	6	7¾		15	40 5	10¾	1¼	
16	26 7	5	5		16	26 9	4	2	3·10	16	40 3	6	8	6·91	16	40 3	10¾	1¼	6·18
17	26 8	5	5	4·91	17	26 11	4	2	3·10	17	39 10	6	8		17	39 10	10¾	1¼	
18	26 7	5	5		18	26 9	4	2		18	39 9	6	8	7·00	18	39 9	11	1	6·18
19	26 2	5	5	5·00	19	26 3½	3½	2	2·80	19	41 10½	4	10½	7·25	19	41 8½	9½	2½	6·18
20	25 5	4½	5	4·75	20	25 8	3	2		20	41 7½	3	10¾	6·87	20	41 5½	8½	2½	5·66
21	24 7	5	4		21	24 10¼	2¾	2	2·69	21	39 6	3	11	7·00	21	39 5	8	2	5·15
22	24 3½	5½	3½	4·50	22	24 6	4	2	2·62	22	37 5	3	7	5·00	22	37 4	8	2	5·15
23	24 8	5	4	4·50	23	24 10	4	2	3·10	23	36 4	4	7		23	36 3	8	2	
24	26 6	5	4		24	26 7½	4	2	3·10	24	36 1	5½	7	5·87	24	36	7	2½	5·01
25	26 11	5	5	4·75	25	27 1	4	2	3·21	25	36 2½	5	7		25	36 1½	6¾	2¼	
26	27 4½	5	5	5·00	26	27 6	4½	2		26	36 5¾	5¼	6¾	6·00	26	36 5	6	2½	4·50
27	28 4	5	5	5·00	27	28 5½	4½	2	3·34	27	37 0	5	7		27	36 11	5½	2	
28	29 4	5	5	5·00	28	29 5¾	5	1¾	3·47	28	37 9	5	7	6·00	28	37 8	6½	3	4·40
29	30 0	5	5		29	30 1	5	2	3·60	29	38 6	6	6		29	38 6	7	3	4·70
30	30 10½	5	5	5·00	30	30 11	5	2	3·60	30	38 10½	6	6	6·00	30	38 10½	7	3	
31	31 10½	5	5		31	31 11	5	2	3·60	31	39 2	6½	6	6·25	31	39 2¼	7¼	3	5·21

Date.	September 1877. SAIKTHA. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	September 1877. TALOKMOH. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	October 1877. SAIKTHA. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	October 1877. TALOKMOH. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″			′ ″	′ ″	′ ″			′ ″	′ ″	′ ″			′ ″	′ ″	′ ″	
1	38 11	0 6½	0 4½	5·50	1	38 11	0 7½	0 3	5·40	1	35 2½	0 5¾	0 5		1	35 3½	0 3¾	0 3½	
2	38 4	6	4½	5·25	2	38 4½	7	3½		2	35 1	5½	5¼	5·37	2	35 1½	3¾	3¾	
3	37 8	7	4½	5·75	3	38	6	3	4·83	3	34 10½	6½	4	5·25	3	35 ¼	3¾	3¾	3·89
4	36 10	6	4½	5·25	4	37	6	3	4·35	4	34 11¾	4¾	5½	5·12	4	34 11¾	4	3¾	4·01
5	35 6	6	5	5·50	5	35 8	6	3	4·35	5	35 1	4½	5¾		5	35 1½	3¾	3¼	
6	33 4	6	4	5·00	6	33 9	4	3	3·38	6	35 1½	4¾	5½		6	35 2¼	3¾	3	
7	31 3	6	5	5·50	7	31 2	4½	6½	5·33	7	35 2½	5¼	5		7	35 3¼	3	3¾	
8	28 8½	7	6	6·50	8	28 9¾	6¼	4	4·96	8	35 4¾	5	5		8	35 5½	3½	3	
9	26 7½	3¾	6	4·87	9	26 8	4	4	3·85	9	35 7¼	5	5½		9	35 8	3½	3	
10	24 7½	2½	6½	4·50	10	24 9	2¾	2¾	2·67	10	35 11	4¼	6	5·14	10	35 11	3½	3	3·44
11	23 7½	3½	5¾	4·62	11	23 8	2	2½	2·28	11	36 1	5	6		11	36 1½	2¾	3½	
12	24 3¾	4	5¾	4·87	12	24 3	2	3½	2·67	12	36 4½	5½	5		12	36 5	2½	3½	3·17
13	26 0¼	3½	5¾	4·62	13	25 11	3	2	2·42	13	36 4½	5½	5	5·33	13	36 5	2½	3½	
14	27 7¾		6¼		14	27 7	3¼	2½	2 67	14	36 1¾	5¾	4¾	5·25	14	36 3	2½	3½	3·10
15	28 9¼	4¾	5¼	5·00	15	28 9	3¼	1¾	2·42	15	35 3½	6	4½		15	35 5	2½	3½	
16	29 4½	4½	6½	5·50	16	29 5	3¼	2¾	2·90	16	35 1¼	5¾	4¼	5·12	16	35 2½	3½	3¼	3·30
17	30 4¾	4¼	5¾	5·00	17	30 4¼	3¼	2¼	3·15	17	34 2¼	5¼	4¼	4·25	17	34 4	3½	3¼	3·62
18	31 2	4½	5	4·62	18	31 2	4	2½	3·28	18	33 2¼	5½	4¾	5·25	18	33 4	3¾	3¼	3·62
19	31 8½	4¾	5¼	5·00	19	31 9¼	4	2¼		19	32 1¾	6	5¼	5·62	19	32 3	4	4	4·14
20	32 4¾	4½	5½	5·00	20	32 5	4	2	3·00	20	30 1¾	4½	5¼	4·87	20	30 2½	6¼	1¾	3·88
21	33 1¼	5	4½		21	33 ¾	4½	2¼	3 41	21	28 5	4¼	6	5·12	21	28 5½	6	1½	3·88
22	33 7	5¾	4	4·75	22	33 7½	4	2½	3·20	22	27 5½	3½	6½	5·00	22	27 5	6	2	4·14
23	34 1¼	5½	4¾		23	34 2	4¼	2¼	3·15	23	25 3½	3½	6	4·75	23	25 2	6	3	4·65
24	34 7	5¾	4½	5·12	24	34 8		7½		24	24 7¼	3½	4¼	3·87	24	24 4½	2¾	3	2·97
25	35 1	5½	5½		25	35 1	4½	3		25	25 1½	4½	2¾	3·62	25	24 11¼	4	2	3·10
26	35 4	6½	4¼		26	35 5½	5	3	3·75	26	27 1	3	5¼	4·12	26	27	3	2	2·53
27	35 7½	5½	5¼		27	35 8	4¼	3¾	4·10	27	24 5½	3½	4¾	4·12	27	24 4	3	2	2·53
28	35 7¾	4½	5¼	5·28	28	35 8¼	4¼	3¾		28	22 7¾	2¼	3½	2·87	28	22 8	2¾	2½	2·71
29	35 6¾	5½	5		29	35 7¼	4¼	3¾		29	21 3¼	2¾	4	3·37	29	21 4	3¼	2¼	2·84
30	35 5½	5¾	5	5·312	30	35 6¼	3¾	3½		30	20 1½	2½	3¾	3·12	30	20 1	3	2	2·53
										31	19 7½	2½	4	3·25	31	19 7	3	2	2·53

Appendix VI.—concluded.

Measurements of River Surface Slope at Saiktha *and* Talokmoh.

November 1877					November 1877					December 1877					December 1877				
Date.	Saiktha. Gauge Reading.	Saiktha. 1st Difference.	Saiktha. 2nd Difference.	Saiktha. Average per mile.	Date.	Talokmoh. Gauge Reading.	Talokmoh. 1st Difference.	Talokmoh. 2nd Difference.	Talokmoh. Average per mile.	Date.	Saiktha. Gauge Reading.	Saiktha. 1st Difference.	Saiktha. 2nd Difference.	Saiktha. Average per mile.	Date.	Talokmoh. Gauge Reading.	Talokmoh. 1st Difference.	Talokmoh. 2nd Difference.	Talokmoh. Average per mile.
	′ ″	′ ″	′ ″			′ ″	′ ″	′ ″			′ ″	′ ″	′ ″			′ ″	′ ″	′ ″	
1	19 9¾	0 2¼	0 4		1	19 9	0 2	0 2½		1	10 11	0 3½	0 1⅜		1	10 11	0 2¼	0 2¼	
2	19 10	2¼	4	3·23	2	19 9¼	2	2½	2·32	2	10 9	2½	2⅜		2	10 9	2¾	1¼	2·14
3	19 7	2¼	4		3	19 6	3	2½		3	10 6½	2⅜	2½		3	10 6½	3	1	
4	19 5	2½	4¾	3·37	4	19 4½	3	2	2·69	4	10 3¼	3¾	1¼		4	10 3½	3½	1½	
5	20 2½	2½	4½		5	19 11½	1¾	3		5	10 1¼	3	2¼		5	10 1	2¾	1¼	
6	20 7	3	4⅜	3·687	6	20 6	3	2½	2·63	6	10	3½	1⅜	2·60	6	10 ¼	3	1½	2·27
7	20 2	3	4¼	3·62	7	20 1¼	1¾	3	2·44	7	10 2	3½	1½		7	10 2	3¼	1¼	
8	19 6½	3	4¼		8	19 6	2	3		8	10 5	3½	1½		8	10 4½	3	1½	
9	19 2½	2½	4½	3·562	9	19 1½	1½	3		9	10 7⅜	3½	1½		9	10 7	3	1½	
10	18 11¼	2½	4		10	19 ¼	1½	1⅜	4·40	10	10 8½	3½	1½	2·50	10	10 8	3¼	1	2·32
11	18 9	3	4	3·37	11	18 9¾	1½	1⅜		11	10 5½	3½	1½		11	10 6¼	3½		
12	18 9½	3	4		12	18 10¼	1½	1⅝	1·67	12	10 1	3½	1½	2·50	12	10 1¾	4	¾	2·32
13	18 10½	3	4	3·50	13	18 10¾	1½	2¾	1·92	13	9 9½	3	1½		13	9 10	4	½	
14	18 10¼	2¾	4½		14	18 9½	1½	2¾		14	9 6	3	1		14	9 7½	4	½	
15	18 4¼	2¾	4¾	3·687	15	18 3¾	1¼	3	2·18	15	9 3½	3	1		15	9 4¼	3¾	¼	
16	17 4½	3	4¾	3·87	16	17 3¾	1¼	3	2·18	16	9 1	3	1¼	2·093	16	9 1¾	3¼	¼	
17	16 4	3	4¾	3·87	17	16 3½	2	2¾	2·43	17	8 10½	3	1½		17	8 11	3	½	
18	15 6	3	4	3·50	18	15 7	1¼	2¾		18	8 8¼	2	⅝		18	8 9	3	½	
19	14 10	3¼	2¾		19	14 10¼	¾	3	1·98	19	8 6½	2	1		19	8 7	3½	½	
20	14 4¼	3¼	2¾	3·00	20	14 3¾	1¼	3		20	8 5	2¼	1		20	8 5	3½	½	
21	13 10¾	2½	3		21	13 9½	1¼	3	2·18	21	8 3¾	2¼	1		21	8 4	3½	½	
22	13 6¾	2¼	1¼		22	13 4	1¼	3		22	8 2	2½	1		22	8 2½	3½	½	
23	13 1½	1½	2¾	2·437	23	13	1¼	2¾	2·12	23	8 3¼	2¼	1¼	1·69	23	8 1	3½	½	
24	12 8½	1½	2½		24	12 7	1¼	2¾		24	7 11½	1⅜	1¼		24	7 11	3½	½	
25	12 5¼	1⅜	2¼		25	12 4	1	3		25	7 10	1½	1½		25	7 9½	3¼	½	
26	12 2	2¼	2	2·04	26	12 1¼	1	2¾	2·00	26	7 8¼	1⅜	1¾		26	7 7¾	3¼	½	
27	11 10	2	2		27	11 9	1	3		27	7 6¼	2	1¼		27	7 6	3¼	½	
28	11 7½	2½	2½		28	11 6½	1½	2½		28	7 5¼	1¾	1¼		28	7 4½	3¼	½	
29	11 4¼	3½	2		29	11 4	1	3¼	2·18	29	7 4	1½	1¼		29	7 3	3		
30	11 1¾	3¼	1¾	2·437	30	11 1½	2½	2		30	7 3	1½	1¼		30	7 1½	3¼	1¼	
										31	7 2	1¼	1¼	1·484	31	7 ½	3¼	1	

January 1878.					January 1878.					February 1878.					February 1878.				
	′ ″	′ ″	′ ″			′ ″	′ ″	′ ″			′ ″	′ ″	′ ″			′ ″	′ ″	′ ″	
1	7 ¾	0 1¼	0 1	1·12	1	6 11½	0 3½	0 1		1	4 11½	0 1¾	0 ⅜	1·25	1	4 9¾	0 4¾	1½	
2	6 11½	1½	1¼		2	6 10¼	3½	1		2	4 10½	1½	½	1·12	2	4 8½	4¾	1⅝	
3	6 10½	1	1¼		3	6 9	3½	1		3	4 9¼	2	½	1· 2	3	4 7½	4¾	1⅝	
4	6 9½	1	1¼		4	6 7¾	3¼	1¼		4	4 8¼	2	½	1· 2	4	4 6½	4¾	1⅝	
5	6 8½	1¼	1¼		5	6 7	3¼	1¼		5	4 7½	2	½	1· 2	5	4 5⅝	5	1½	
6	6 7½	1¼	1⅜		6	6 5⅜	3½	1¼		6	4 6½	2¼	½	1·37	6	4 5	1	1½	
7	6 6	1½	1		7	6 4½	4	1		7	4 5½	2¼	¼	1·37	7	4 4¼	5	1½	
8	6 5	1¼	1		8	6 3¾	3¾	1		8	4 4½	2¼	¼	1·50	8	4 3½	5	1½	
9	6 4¼	1⅜	¼	1·19	9	6 3⅜	3⅜	1	2·42	9	4 4¼	2¼	¼	1·37	9	4 3	5	1⅝	
10	6 5	1⅜	¼		10	6 4	4¼	1		10	4 4	2⅜	¼	1·37	10	4 2¼	5	2¼	
11	6 8	1½	¼	1·37	11	6 7	4	1		11	4 3⅝	2⅜	¼	1·37	11	4 2¼	5⅝	2¼	
12	7¼	1¼	¾		12	6 11¼	4½	1		12	4 3½	2		1·00	12	4 2	5¼	2	
13	7½	2¼	⅝	1·25	13	7 1	4¼	¾	2·75	13	4 3¼	1⅝		1·37	13	4 1¼	5¼	1½	
14	6 11¾	2¼	¾		14	6 11¼	4¼	1		14	4 2¼	1⅝	¼	1·00	14	4	6	1	
15	6 8¾	2¼	½		15	6 8¼	4½	1		15	4 3¼	0			15	3 11½	6	1	
16	6 5½	2	½		16	6 4¼	4¾	1¼		16	4 1¼	1	¼	0·75	16	3 10¼	6	1¼	
17	6 3	1½	¼		17	6 2¼	5	¾		17	3 11½	1¼	¼	0·25	17	3 9½	6	1¼	
18	6 1	1½	¼	1·30	18	6	4¼	1½		18	3 11	1¼	¼	0·25	18	3 8¾	6	1¼	
19	5 11	1½	¼		19	5 10	4¾	1		19	3 10½	1	½	0·62	19	3 8¼	6	1¼	
20	5 9½	1½	¼		20	5 8½	4¾	1		20	3 11	2	1¼	1·12	20	3 8½	6	1¼	3·74
21	5 8	1½	¼		21	5 7¾	4¼	1¼		21	4 1¾	1	¼	0·62	21	3 11¼	6	1¼	
22	5 6¾	1½	⅓		22	5 5¼	5	1¼		22	4 5¼	1¼	¼	0·25	22	4 2½	6¼	1½	
23	5 5½	1¾	⅓		23	5 4	4¾	1¼		23	5 4	¾	½	0·37	23	5 1½	5½	1½	
24	5 4½	1¾	⅓		24	5 3	4¾	1¼		24	5 8	2¼	1	1·12	24	5 5¼	7	1	
25	5 3½	2	½		25	5 2	4¾	1¼		25	5 9¼	2	1	1·50	25	5 7¼	6½	1½	4·02
26	5 2¾	1¾	½		26	5 1½	4⅝	1		26	5 7¾	1¾	1	1·37	26	5 5	6	2	
27	5 2¼	1¾	½		27	5⅝	4⅝	1¼		27	5 7	¾	1		27	5 2	6	2	
28	5 2	1¼	½		28	5½	4⅝	1¼		28	5 2	1½	1	1·25	28	5	6	1½	
29	5 1¾	1¾	½		29	5½	4¾	1¼											
30	5 1¼	1¾	½		30	4 11¾	4¾	1½											
31	5 1¼	1¾	½	1·05	31	4 10¾	4¾	1½											

Appendix VII.

Measurement of River Surface Slope at **Myanoung** *and* **Kyungalay**.

March 1877. — MYANOUNG.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″	
1	0 5	0 1½	0 2	
2	0 3	1½	2	1·759
3	0 4½	1½	2	
4	0 1½	1½	2	
5	0 ¾	1½	2	
6	0 8½	1½	2	
7	0 8	1½	2	
8	0 7½	1½	2	
9	0 7	1½	2	
10	0 6	1½	2	
11	0 6	1½	2	1·759
12	0 6½	1½	2	
13	0 7½	1½	2	
14	0 7¾	1½	2	1·759
15	0 7	1¾	2	
16	0 7	1¾	2	
17	0 6¾	1¾	2	
18	0 6½	1¾	2	
19	0 5¾	1¾	1¾	
20	0 5	2	1½	
21	0 4¾	1¾	1¾	1·794
22	0 6	1½	2	
23	0 8¾	1½	1¾	
24	0 5	1¾	2	
25	0 9½	1	2¼	1·727
26	1 1½	1	1¾	
27	1 5	2½	3	
28	1 9½	1½	2¼	1·633
29	2 0	1½	2¾	
30	2 0	1½	2¾	2·136
31	1 10	1½	2¾	2·136

March 1877. — KYUNGALAY.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″		
1	0 0	0 ½		
2	0 2	½		·50
3	0 ½	½		·50
4	0 3½	½		
5	0 4½	½		
6	0 5½	½		
7	0 6	½		
8	0 6½	½		
9	0 7	½		
10	0 8	½		
11	0 8	½		·50
12	0 7½	½		
13	0 6½	½		
14	0 6½	½		·50
15	0 8	½		
16	0 8	½		
17	0 8	½		·45
18	0 8¾	¼		
19	0 8¾	½		
20	0 8	½		
21	0 7¾	½		·50
22	0 8¾	¼		·50
23	0 6¾	¼		
24	0 1¾	0		
25	0 2¾	¼		·25
26	0 7	1		
27	0 11	½		·75
28	1 3	¼		
29	1 5¼	¼		
30	1 5¼	¼		·33
31	1 3¼	¼		·25

April 1877. — MYANOUNG.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″	
1	1 9¾	0 1	0 3	2·010
2	2 6¼	¾	2½	1·633
3	3 9¼	¾	1¾	1·256
4	4 7¼	¾	2	
5	4 10	1	2¼	
6	4 10	1	2¼	1·549
7	4 8½	1¾	2	1·884
8	4 8½	1½	2	
9	4 10	1	2¼	
10	4 10¼	1	2½	1·7139
11	4 9	1	1¾	
12	4 9	1	1¾	
13	4 9	1	1¾	
14	4 7¾	1	1¾	
15	4 4¼	1	1½	
16	4 0	1	3¼	1·987
17	3 8	1¾	1¾	
18	3 3¾	1¼	2	
19	3 0½	1	2	1·633
20	2 10	1¼	1¾	
21	2 9¼	1	1¾	
22	2 8¼	1	1¾	
23	2 7½	1	1¾	
24	2 7	1	1¾	1·407
25	2 9	1	2	1·507
26	3 3	1	2	
27	3 8	1	2	1·507
28	3 7¼	1	2	
29	3 3	1	2	1 507
30	2 11¾	1¼	2	1·633

April 1877. — KYUNGALAY.

Date.	Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″		
1	1 2¾	0 ¼		·25
2	1 10¾	¼		·25
3	3 3¼	½		·50
4	4 0	¾		
5	4 3	¾		
6	4 3	½		·616
7	4 2	¾		
8	4 2	¾		·75
9	4 3	½		
10	4 3¼	½		·50
11	4 2	¼		
12	4 2	¼		
13	4 2	¼		
14	4 3¾	¾		·375
15	3 9	½		
16	3 4½	¼		
17	3 ½	¼		·333
18	2 8¾	¼		
19	2 5	¼		
20	2 3	¼		
21	2 2¼	¼		
22	2 1½	¼		
23		¼		
24	2 ¼	¼		·25
25	2 2¼	¼		
26	2 8¼	¼		
27	3 1½	¼		·25
28	3 ¼	¼		
29	2 8¾	¼		
30	2 4¾	¼		·25

May 1877. — MYANOUNG.

	′ ″	′ ″	′ ″	
1	2 8	0 ¼	0 2	
2	2 6¼	¼	2	
3	2 6½	¼	1¾	
4	2 4	1¼	2	
5	2 2¾	1½	2	
6	2 1¼	1¼	1¾	
7	2 1½	1¼	1¾	
8	2 1¼	1¼	1¾	
9	2 ¾	1¼	1¾	
10	2 0	1¼	1½	1·394
11	1 10	1¼	1½	
12	1 8	1¼	1¼	
13	1 7	1¼	1¼	
14	1 6¼	1½	1¼	
15	1 5¼	1¼	1¼	
16	1 5½	1¼	1½	1·277
17	1 6½	1¼	1¼	
18	1 9	1½	1¼	
19	1 11¼	1¼	1¼	1·256
20	2 ¼	1½	1¼	
21	2 ¾	1¼	1¼	1·256
22	2 ½	1½	1½	1·256
23	2 1	1½	1¼	
24	2 4¾	1¼	1¼	
25	2 11	1¼	1¼	1·256
26	3 3¾	1¼	1½	1·382
27	3 3	1¼	1½	1·382
28	3 8½	1¼	1½	1·382
29	6 0	1¼	1½	1·382
30	8 1½	1¼	1½	1·382
31	9 11¾	1¼	2	1·633

May 1877. — KYUNGALAY.

	′ ″	′ ″		
1	2 1	0 ¼		
2	1 11¼	¼		
3	1 11¼	¼		·25
4	1 9	¼		
5	1 7¾	¼		
6	1 6¼	¼		
7	1 6¼	¼		
8	1 6¼	¼		
9	1 5¾	¼		
10	1 5	¼		
11	1 3	¼		
12	1 1	¼		
13	1 0	¼		
14	0 11¼	¼		
15	0 10¼	¼		
16	0 10¼	¼		·25
17	0 11½	¼		
18	0 2	¼		
19	1 4¼	¼		
20	1 5¼	¼		
21	1 5¾	¼		·25
22	1 5½	¼		·25
23	1 6	¼		
24	1 9¾	¼		
25	2 4	¼		
26	2 8¾	¼		·25
27	2 8	¼		·25
28	3 1½	¼		·25
29	5 5	¼		·25
30	7 6	¼		·25
31	9 4¾	¼		·25

June 1877. — MYANOUNG.

	′ ″	′ ″	′ ″		
1	11 2½	0 2	0 2¼	2·136	
2	12 ¼	2	2¼	…	
3	12 11¼	2	2¼	2·136	
4	13 2½	2	2¼	2·136	
5	15 5	2½	2¼	2·261	
6	14 10½	2	2¼	2·136	
7	13 2½	2	2¼	…	
8	11 11½	2	2¼	…	
9	10 2¾	2	2¼	…	
10	9 2¼	2	2¼	…	
11	9 ⅜	2	2	…	
12	9 ¼	1¾	2	2·010	
13	9 1¾	1¾	2	…	
14	9 3½	1¾	2	1·884	
15	9 1¾	1½	2	1·759	
16	9 8	1½	2	1·759	
17	10 10¾	1¾	2	1·884	
18	13 7	2½	2¼	2·387	
19	16 8½	2	2¼	2·136	
20	18 8½	2	2¼	…	
21	20 1½	2¼	2¼	…	
22	20 10¼	2¼	2¼	2·261	
23	22 3¼	2¾	2	2·387	
24	23 9¼	2½	2½	…	
25	24 2¾	2¼	2½	…	
26	25 8½	2½	3	2·763	
27	25 2¾	2½	3	…	
28	24 11	2½	3	2·638	
29	25 2¼	2½	3	…	
30	25 9½	2½	3¼	2·827	

June 1877. — KYUNGALAY.

	′ ″	′ ″		
1	10 8½	0 ¼		·25
2	11 6	¼		·25
3	12 5	¼		
4	12 8¼	¼		·25
5	14 11	¼		·25
6	14 4¼	¼		·25
7	12 8¼	¼		·25
8	11 5¼	¼		·25
9	9 8½	¼		·25
10	8 8	¼		
11	8 6½	¼		
12	8 5¾	¼		·25
13	8 7¼	¼		
14	8 8¾	¼		·25
15	8 7	¼		·25
16	9 1¼	¼		·25
17	10 4½	¼		·25
18	13 0¾	1		·25
19	16 3	1		1·00
20	18 3	1		1·00
21	19 8¼	1		1·00
22	20 5	1		1·00
23	21 10½	1		1·00
24	23 4	1		
25	23 9½	1		1·00
26	25 3½	1		1·00
27	24 9¾	1		
28	24 6½	1¼		1·125
29	24 9½	1¼		1·125
30	25 4½	1¼		1·125

Appendix VII.—continued.

Measurements of River Surface Slope at Myanoung *and* Kyungalay.

July 1877. July 1877. August 1877. August 1877.

Date.	Myanoung. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	Kyungalay. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	Myanoung. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	Kyungalay. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″			′ ″	′ ″				′ ″	′ ″	′ ″			′ ″	′ ″		
1	25 6	0 2¾	0 3½		1	25 2½	0 1¼			1	34 0	0 3	0 4		1	33 9	0 2		2·00
2	25 4	2¼	3¼	2·952	2	24 11½	1¼		1·25	2	34 7	4¼	3¾	3·769	2	34 4	2		
3	25 10⅜	2¼	3½	2·890	3	25 5	¼		·25	3	35 0	4	4½		3	34 8½	2		
4	26 5¼	2¾	3¼	3·015	4	26 0¾	1½		1·50	4	35 5¼	3½	4½	4·146	4	35 1	2		2·00
5	28 1¼	2¾	3¼	...	5	27 9	1½		1·50	5	35 11¼	3¼	4½	4·062	5	35 6½	2		
6	28 10¾	3¼	3¼	3·141	6	28 7¼	2¼		2·25	6	36 7½	3¼	4¾	4·020	6	36 2½	2		2·00
7	29 7½	1¼	3¼	...	7	29 3	2			7	38 2¼	2¾	4½	3·643	7	37 9	2		2·00
8	29 10¾	2¼	3¼	2·513	8	29 7	2		2·00	8	39 2	3½	5	4·272	8	38 9¼	2¼		2·25
9	29 5¼	2¾	3	2·890	9	29 1¾	2		2·00	9	40 0	3¼	4¾		9	39 8¼	2½		2·25
10	28 8	3	3	3·015	10	28 4½	2		2·00	10	40 8¼	4	5	4·272	10	40 7	2¼		
11	...	...	...	...	11					11	41 ⅜	3⅜	4¼		11	41 ⅜	2¼		
12	27 10½	3	3	...	12	27 7	2		2·00	12	41 1¼	4½	4¼	4·209	12	41 1⅜	2½		2·33
13	27 4½	3½	2⅜	3·078	13	27 0¾	1½			13	40 11	4	4¼		13	40 11½	2½		
14	27 3¾	3½	2¾	3·141	14	27 0	1½		1·50	14	40 10¼	4	4¼		14	40 10⅜	2½		
15	27 8¾	3	3¼	...	15	27 4¾	1⅜			15	40 9½	3	5¼		15	40 9	2		
16	27 11½	3	3¼	3·141	16	27 7½	1⅜			16	40 5⅜	3½	5		16	40 6	2		
17	28 1½	3	3¼	...	17	27 10½	1⅜		1·75	17	40 1⅜	3½	5⅜		17	40 3	2		
18	28 ½	3	3½	3·267	18	27 8⅜	2			18	40 1	3½	5⅜	4·335	18	40 2¼	2		2·167
19	27 7½	4	3⅜	3·769	19	27 4¾	2		2·00	19	41 3¼	3	5¼		19	41 ⅜	2½		
20	26 10⅜	3	3½	...	20	26 7	2		2·00	20	41 8½	3½	5	4·146	20	41 9½	2⅜		2·625
21	26 ⅜	3	3½	3·267	21	25 9	2			21	40 1¼	3¼	5		21				
22	25 8⅜	3	3½	...	22	25 5	2		2·00	22	38 8	3¼	5		22				
23	25 11¾	3	3½	...	23	25 8	2		2·00	23	37 7	4	4¼		23				
24	27 6½	3	3½	...	24	27 2⅜	2		2·00	24	37 2⅜	4⅜	5		24	37 2	1½		
25	28 5½	1½	3½	...	25	28 1	2¾		2·75	25	37 2½	4⅜	5	4·635	25	37 1⅜	1½		1·50
26	28 10	3	3⅜	2·952	26	28 6	2¾		2·75	26	37 4½	4⅜	5		26	37 3½	1½		
27	29 6⅜	3	3¾	3·392	27	29 3	3		3·00	27	37 10	4⅜	5¼	4·963	27	37 11¼	2		1·75
28	30 6½	3	3⅜	...	28	30 2¼	2¼		2·25	28	38 7	3½	7	5·151	28	38 7	2½		
29	31 4	3	4	3·518	29	31 0¼	2½		2·50	29	39 0	3¼	5¼		29	38 11¼	1⅝		2·125
30	32 3½	3	3¾	3·392	30	31 11⅝	2½		2·50	30	39 3½	6¼	5½		30	39 5	1¾		
31	33 1	3	4	3·518	31	32 9½	2½		2·50	31	39 6½	6½	5⅜	5·433	31	39 8¼	2¼		2·00

September 1877. September 1877. October 1877. October 1877.

	′ ″	′ ″	′ ″			′ ″	′ ″				′ ″	′ ″	′ ″			′ ″	′ ″		
1	39 5¾	0 5¾	0 3¼		1	39 8	0 2¼			1	36 5¾	0 4¼	0 4		1	36 4½	0 2½		
2	39 1½	6	3¼	4·586	2	39 3¾	2¼		2·25	2	36 4	5¼	0 3¼		2	36 3¾	2½		
3	38 7½	6¼	4¾	5·654	3	38 8¼	2¼			3	36 3	5¼	3¼		3	36 2¾	2½		
4	37 10½	6¼	3	4·635	4	38 ⅜	2¼		2 25	4	36 2½	5¾	3¾	4·366	4	36 2½	2½		2·50
5	36 8½	6	3	4·523	5	36 9⅜	1½		2·50	5	36 4⅜	5½	3	4·146	5	36 4½	2½		2·25
6	35 1¼	5¾	3¼		6	35 2½	½		·50	6	36 4	5½	3	4·272	6	36 3½	2¼		2·25
7	33 1¼	4¾	4⅜		7	33 1	2½		2·50	7	36 4⅜	5½	3		7	36 4½	2¼		
8	30 9	4¼	4¾		8	30 8¼	2½		2·50	8	36 6	5½	3		8	36 5½	2¼		
9	28 7⅜	4	5		9	28 7½	2½		2·50	9	36 8½	3	3¼		9	36 7¼	2¼		
10	26 4½	4¼	5¼		10	26 3½	2½		2·50	10	36 10½	5	3¼	3·958	10	36 9½	2¼		
11	25 2⅜	4¼	5¼		11	25 2	2½			11	37 1	5	3¼		11	37 0	2¼		
12	25 2¼	4¼	5¼	4·774	12	25 1½	2½		2·50	12	37 2½	5	3¼	4·146	12	37 1½	2¼		
13	26 11½		3½		13	27 3¾	2½		2.50	13	37 5	4½	3¼	3·935	13	37 4	2¼		2·25
14	28 6⅜	4¼	3½	3·895	14	28 5½	2½		2·50	14	37 2¼	5½	3¼	4·397	14	37 1¼	1¾		1·75
15	29 9¾	4¼	4¾	4·523	15	29 8¼	3¾		3·75	15	36 10	6	3		15	36 9½	1¾		
16	30 8½	3¼	3½	3·392	16	30 6½	3¾		3·75	16	36 4⅜	5½	3¼	4·460	16	36 4	1¾		1·75
17	31 8¾	4	3½	3·769	17	31 8¼	4		4 00	17	35 9	6¼	2¼	4·272	17	35 9¼	1¾		1·75
18	32 6½	4	3¾	3·895	18	32 6½	4½		4·50	18	34 9½	5½	2¼	3·895	18	34 9½	1¾		1·75
19	33 2½	3¾	4		19	33 2½	3¾			19	33 7¾	5¼	2½		19	33 7¾	1¾		1·75
20	33 9	4¼	2¾	3·706	20	33 9¾	3½		3·62	20	32 1¼	4	2¼	3·141	20	32 1	3		3·00
21	34 5	4	2½		21	34 6	3¾		3·75	21	30 9	4	2¼		21	30 8¾	3		3·00
22	34 11	4¼	2¼	3·267	22	35 0½	4			22	28 11	4	2¼		22	28 10¾	3		3·00
23	35 5½	4½	3	3·769	23	35 6	4			23	27 2¼	5	2¾	3·895	23	27 1¾	3		3·00
24	35 10½	4¼	3	3·706	24	35 11½	4¼		4 05	24	25 9	5	2½	3·769	24	25 8½	3		3·00
25	36 2½	4¼	3¼		25	36 4	4½			25	26 11	5	2¾	3·895	25	25 10½	3		3·00
26	36 6½	5	3		26	36 8½	4½			26	28 7½	4½	3½	4·020	26	28 6¾	4¾		4·75
27	36 8¾	5½	3		27	36 10¾	4¼		4·416	27	25 10¾	4½	3¼	3·895	27	25 10½	2½		2·50
28	36 9	5½	3	4·114	28	36 10½	4½			28	24 4	3½	3¼	3·392	28	24 1¾	2½		2·50
29	36 8¼	5¾	3		29	36 9¼	3¾			29	22 5	3½	3½	3·518	29	22 2¾	2½		2·50
30	36 7¼	4½	4	4209	30	36 7	3½		3·958	30	20 10	3½	3½		30	20 7¾	2½		2·50
										31	20 3¾	3	3½	3·392	31	20 1	2¼		2·50

Appendix VII.—concluded.

Measurements of River Surface Slope at Myanoung *and* Kyungalay.

November 1877.

Date.	Myanoung. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	Kyungalay. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″			′ ″	′ ″		
1	20 2½	0 3	0 4½	3·643	1	19 11½	0 2		2·00
2	20 3¾	3¼	4¾	4·020	2	20 1	1¼		1·25
3	20 ¼	3½	4¾		3	19 9½	1¼		
4	19 10	3½	4¾	4·146	4	19 7¼	2¼		1·75
5	20 4½	1½	4¼	2·890	5	19 11¾	2¼		2·25
6	21 3	3	5½	4·272	6	21 0	2½		2·50
7	20 9¾	3	5½		7	20 6½	2½		2·50
8	20 2½	3	5½	4·272	8	19 11½	2½		
9	19 7½	3	5½		9	19 4½	2½		2·50
10	19 5¼	3	5½		10	19 2¼	2½		
11	19 ¼	3	5½		11	18 9¾	2½		
12	19 ¼	3	5½	4·272	12	18 9¼	2½		2·50
13	19 2¼	3	5½		13	18 11¼	2½		
14	19 2¾	3	5½	4·272	14	18 11¾	2½		2·50
15	18 9	4	4½		15	18 7	2½		2·50
16	17 9½	2½	6	4·146	16	17 5¾	2¼		2·25
17	16 9	2¼	6		17	16 5¼	2¼		2·25
18	15 8¾	2¼	6¼	4·272	18	15 4¼	1¾		1·75
19	14 0¾	3¾	6¼	5·261	19	14 5½	2¼		2·25
20	13 11¾	2¼	6¼		20	13 8¾	2¼		2·25
21	13 3¾	2¼	6¼	4·272	21	13 1	2½		2·50
22	12 9½	1¾	6¾		22	12 6¼	2½		
23	12 4	2	6½	4·272	23	12	2		2·25
24	11 11	1¾	6¾		24	11 7½	2		2·00
25	11 6½	1¾	4¾		25	11 2¾	2		
26	11 3	1½	4¾	3·476	26	10 11¼	2		
27	10 11	1¾	5¾		27	10 7¼	2		
28	10 8	1½	5¾		28	10 4½	2		2·00
29	10 4¼	1½	5¾		29	10 ½	2		
30	10 1¼	1½	5¾	3·675	30	9 9½	2		2·00

December 1877.

Date.	Myanoung. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.	Date.	Kyungalay. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″			′ ″	′ ″		
1	9 10¼	0 1½	0 6¾		1	9 6½	0 2		
2	9 7½	1½	5½		2	9 3¾	2		2·00
3	9 4¾	1½	5½		3	9 1	2		
4	9 2	1½	4½	3·549	4	8 10¼	2		
5	8 11½	1¾	7¼		5	8 8	2		
6	8 10	1¾	5	3·955	6	8 6¼	2		2·00
7	8 11¾	1½	5½	3·518	7	8 7¾	2		2·00
8	9 4¼	1½	5¼		8	9 ¼	2		
9	9 7¼	1½	5¼		9	9 3¼	2		
10	9 9½	1½	5¼	3·432	10	9 5½	2		2·00
11	9 7	1½	5¼		11	9 3	2		2·00
12	9 2	1½	6	3·581	12	8 10¼	2		
13	8 9¼	1	5¼		13	8 5½	2		2·00
14	8 4¾	1½	5¼		14	8 1	2		
15	8 1	1½	5¼	3·311	15	7 9¼	2		
16	7 10½	1½	5¼		16	7 6¾	2		
17	7 7¼	1½	5¼		17	7 3½	2		
18	7 4½	1½	5¼		18	7 ¾	2		
19	7 3¾	1½	5¼		19	7 0	2		2·00
20	7 ¼	2¼	5¼	3· 42	20	6 8¾	2		
21	6 10¾	1½	5½		21	6 7	2		
22	6 9½	1¼	6		22	6 5¼	2		
23	6 8½	1	6¼		23	6 4	2		2·00
24	6 6½	1	6¼		24	6 2	2		
25	6 4¾	1	6¼		25	6 ¼	2		
26	6 3	1	6¼		26	5 10½	2		
27	6 ¾	1	6¼	3·626	27	5 8¼	2		
28	5 11	1	6¼		28	5 6½	2		
29	5 9½	1	6¼		29	5 5	2		
30	5 8	1	6¼		30	5 3½	2		
31	5 7¼	1¼	6¾		31	5 2¾	2		

January 1878.

	Myanoung. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.		Kyungalay. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″			′ ″	′ ″		
1	5 5½	0 1	0 6¾		1	5 1	0 2		2·00
2	5 4½	1	6¾		2	4 11¾	2		
3	5 3	¼	6¾		3	4 10	2		
4	5 1¾	¼	6¾		4	4 8¾	2		
5	5 ¾	¼	6¾	3·745	5	4 7¾	2		
6	4 11½	¼	6¾		6	4 6½	2		
7	4 9¾	¼	6¾		7	4 4¾	2		
8	4 9¼	0	7¼		8	4 3¾	2		
9	4 8¾	0	7¼	3·643	9	4 3¼	2	2·00	
10	4 9½	0	7¼		10	4 4	2		
11	5 1½	0	7¼		11	4 8	2	2·00	
12	5 6½	0	7¼		12	5 1	2		
13	5 9	0	7¼	3·643	13	5 3¼	2	2·00	
14	5 8½	0	7¼		14	5 3	2½	2·00	
15	5 4	¾	7¼		15	4 11¾	2		
16	5 ¼	¾	7¼	3·895	16	4 7½	2		
17	4 9	¼	7¼		17	4 3½	2	2·125	
18	4 6	¼	7¼		18	4 ¾	2		
19	4 4	¼	7¼		19	3 10¾	2		
20	4 2½	¼	7¼		20	3 9	2		
21	4 ¾	¼	7¼	3·769	21	3 7½	2		
22	3 11½	0	7¼		22	3 6	2		
23	3 10	¼	7¼		23	3 4¾	2		
24	3 8¾	¼	6¾		24	3 3½	2	2·00	
25	3 7½	¼	6¾		25	3 2¼	2		
26	3 7	¼	6¾		26	3 1¾	2		
27	3 6¼	¼	6¾		27	3 1	2		
28	3 6	¼	6¾		28	3 ¾	2		
29	3 6	¼	6¾		29	3 ¾	2		
30	3 5¼	¼	6¾		30	3 0	2		
31	3 4¼	0	7		31	2 10¾	2		

February 1878.

	Myanoung. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.		Kyungalay. Gauge Reading.	1st Difference.	2nd Difference.	Average per mile.
	′ ″	′ ″	′ ″			′ ″	′ ″		
1	3 2½	0 1¼	0 6¾		1	2 9¼	0 2		
2	3 1½	¼	6¾		2	2 8½	2		
3	3 0	¼	6¾	3·52	3	2 6¾	2		
4	2 11¼	¾	7		4	2 5¾	2		
5	2 10¼	¼	6½		5	2 5	2		
6	2 8¾	¼	6½		6	2 3½	2		2·00
7	2 7¾	¼	6½		7	2 2½	2		
8	2 7¾	¼	6½		8	2 2	2		
9	2 6½	¼	6½		9	2 1¼	2		
10	2 6¼	¼	6½		10	2 1	2		
11	2 6¼	¼	6½		11	2 1	2		
12	2 6¼		7¼		12	2 ¼	2		
13	2 4½	½	6¼		13	1 11¼	2		
14	2 3½	¼	6½		14	1 10¼	2		
15	2 2	¼	6½		15	1 8¾	2		
16	2 ¾	¼	6½		16	1 7½	2		
17	1 11½	¼	6½		17	1 6¼	2		
18	1 10½	¼	6½		18	1 5¼	2		
19	1 10	¼	6½		19	1 4¾	2		2·00
20	1 10½	¼	6½	3·392	20	1 5½	2		
21	2 0	¼	6½		21	1 6¾	2		
22	2 4¾	¼	6½	3·392	22	1 11½	2		2·00
23	3 1¾	¼	6½		23	2 8½	2		2·00
24	3 10½	¼	7½	3·643	24	3 5¼	2		
25	4 1½	½	7¼	3·895	25	3 8½	1¾		1·875
26	4 0	¼	7½		26	3 6¾	2		
27	3 9	¼	7½		27	3 3¾	2		
28	3 5¾	¼	7½	3·895	28	3 ½	2		2·00

SUPPLEMENT.

D.

The Discharge of the Irrawaddy in 1878 and 1879.

The length of time that has elapsed between the drawing up of the earlier parts of this Report and the printing of it have permitted additions to be made to the records of the discharge of the Irrawaddy, which, calculated from the Myanoung gauge register, are brought up to the end of December 1879. An abstract of these discharges for each month and year from 1869 to 1879 is given in Table 14 A, over the leaf, while the calculated daily discharges are given in Appendix V.

From a comparison of Tables 14 and 14 A. it is manifest that the last two years have increased the average discharge of the river, owing to the comparatively great volume of water brought down in the present year, during which a total of 519,132 millions of metre-tons has been discharged. During 1878, notwithstanding that the rains were unusually delayed, the high discharge of 463,146,740,210 metre-tons passed Myanoung. This has only previously been exceeded during the flood years 1871, 1875 and 1877. The average fall is thus raised from 425 to 441 billion tons yearly.

The monthly totals for 1878 call for little remark, except that in June the lowest discharge for that month yet recorded is found, or 17,895 million tons against an average of 33,645, and a previous minimum in 1872 of 21,036 million tons. The other months of the year are about or above the average, the last four months having large excesses, but not in any case reaching the maximum amounts of previous years.

The first five months of 1879 appear about the average, but a striking departure from it is shewn in June, when 62,273 million tons were discharged against an average of 33,645, a previous maximum of 45,354, which occurred in 1875, and the minimum of 17,895 of 1878. This was followed by the equally unusual discharge of 107,410 million tons in July, the average being 83,050, and the next greatest in 1875 reaching 94,027 millions. In August 110,667 millions are recorded, against an average of 96,731, and a maximum in 1877 of 122,604 million tons. In September a maximum discharge of 100,659 million tons is recorded, which is 20,000 million above the average. For the four months taken together there was a discharge of 87 billion tons above the average, or nearly 22 billions per month; three out of four recording the highest discharges ever known.

Table 14 A.

Discharge of the Irrawaddy River at Myanoung in Metre tons.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total discharge for each year.
1869 ...	...	...	...	...	...	34,765,499,860	76,105,405,900	83,129,560,800	71,926,954,600	67,585,097,800	14,548,196,480	...	...
1870 ...	...	5,352,928,040	4,723,168,500	5,703,339,980	7,489,372,280	23,889,172,240	83,128,778,160	93,661,181,220	87,377,200,500	53,624,269,540	19,922,747,040	12,839,276,440	405,495,994,900
1871 ...	7,931,747,860	5,248,853,960	6,768,772,420	9,339,342,640	11,555,532,840	44,536,287,840	88,977,030,860	102,173,847,920	94,451,981,760	58,366,151,900	36,701,425,700	15,588,073,600	481,639,049,300
1872 ...	9,852,990,780	6,798,773,620	6,212,467,160	6,517,161,600	14,014,777,860	21,036,761,600	85,529,495,380	94,557,343,680	77,758,373,400	81,917,359,980	32,915,434,980	14,445,287,360	451,556,227,400
1873 ...	9,640,860,600	6,663,855,280	6,466,004,340	6,594,821,880	8,663,618,960	37,160,697,280	68,222,287,000	85,100,009,680	63,013,555,700	52,263,959,240	26,986,522,480	10,812,722,460	381,588,894,900
1874 ...	6,706,840,840	4,812,304,380	6,491,819,560	10,672,768,480	18,234,967,180	23,806,945,980	73,196,606,040	66,859,213,000	75,221,939,260	64,483,583,320	26,662,689,780	11,787,789,580	388,937,467,400
1875 ...	7,819,046,720	5,538,467,980	6,087,990,460	10,983,351,300	21,647,452,920	45,354,289,660	94,027,283,760	109,506,569,980	84,249,129,570	49,939,140,050	19,734,342,580	10,575,437,040	465,442,502,020
1876 ...	6,662,423,840	4,665,610,940	6,171,721,380	9,003,367,300	10,555,613,960	27,887,805,580	88,970,275,980	98,754,458,200	53,141,862,860	46,041,450,880	19,535,670,080	10,277,036,180	381,667,297,180
1877 ...	5,978,016,080	4,463,610,440	4,166,609,100	8,055,460,540	7,140,188,860	31,489,827,520	66,882,182,700	122,604,179,620	86,515,369,560	84,336,110,520	30,300,861,080	14,187,872,920	466,120,288,940
1878 ...	9,351,174,360	6,311,425,340	8,731,902,860	10,672,619,840	10,847,044,760	17,895,024,100	81,101,920,600	97,028,527,560	92,370,402,690	82,232,264,340	31,733,543,520	14,870,890,240	463,146,740,210
1879 ...	9,425,172,980	6,717,836,240	7,273,284,480	6,596,626,560	9,460,500,720	62,273,271,400	107,410,040,160	110,667,145,380	100,659,736,540	55,722,121,440	29,917,827,920	13,008,421,100	519,131,983,920
Total ...	73,368,274,060	56,573,666,220	63,093,740,260	84,138,860,120	119,609,070,340	370,095,583,060	913,551,306,540	1,064,042,037,040	886,686,506,440	696,511,509,010	288,959,261,640	128,392,806,920	4,404,726,446,170
Yearly & monthly average.	8,152,030,451·	5,657,366,622	6,309,374,026	8,413,886,012	11,960,907,034	33,645,053,005·	83,050,118,776·	96,731,094,276·	80,607,864,221·	63,319,228,091·	26,269,023,785·	12,839,280,692	440,472,644,617

In this the Irrawaddy has shown similar results to rivers all over the globe. The year 1879 appears to have been one of the wettest on record. Casual indications in newspapers prove that parts of America, almost the whole of Europe, Egypt, and extensive tracts of Asia have received an inordinate amount of rain. It has been found impossible to draw up a systematic notice of this from the indications given, as they are, usually, only passing allusions called forth by damage to crops or inconvenience to individuals. Similarly, when in 1874, the writer endeavoured to draw up a record of great floods of different countries from the *Times* and other papers, it was found that few of the principal features or characteristics of the floods were anywhere recorded, and they were only noticed at all, as a rule, owing to some passing calamity they entailed. But during the present year, the indications are so general and widespread, showing, usually, a continuous heavy downpour of rain over extensive areas rather than local falls of great intensity, which are often responsible for causing great damage, that the inference is inevitable that the year 1879 is marked out as one of the wettest upon record. And this notwithstanding that there are localities like Cashmere where famine is felt from want of rain.

It is impossible, at present, to investigate the causes of this excess of moisture, and little more will be done than to state the salient points connected with the 1879 flood. To permit the Plates of the Myanoung gauge diagrams to be brought up to date the gauge readings for the years 1878 and 1879 are given at the end of this note. The discharge diagram can be plotted from Appendix V.

There was a remarkable similarity between the 1875 and the 1879 flood in the early arrival of the great flood wave, in its rapid rise, and in the great volume of water brought down. Another feature, which is sufficiently curious to be recorded, may be noted. It is the Burmese custom to take astrological predictions for each year at the commencement. These are read by Brahmins in the service of the King at Mandalay sometime before the year begins, which usually occurs about February or March, and the predictions, which generally include weather forecasts for the year are announced simultaneously throughout Burma by the Brahmins. Both in 1875 and in 1879 a very heavy flood was foretold for the Irrawaddy, several months before it came down. It was familiar talk amongst the people before the rains began. The 1877 flood was not announced so far as the writer knows, nor the 1871 one; nor has any great flood been foretold which did not come off. It would be useful if the foretellers could ensure correct information on all occasions; but, without attaching any value to the occurrence, it is certainly remarkable that these two floods should have been accurately forecast. Nothing is known of the grounds or the symptoms from which the forecast was made.

The river commenced rising at Mandalay long before it rose in Lower Burma. The accompanying extract from a letter in the *Rangoon Gazette* of 3rd July 1879 shows that at Mandalay early in June there was a rise in circumstances similar to those narrated by Colonel Symes, before quoted:—"We have had no rain up here, only two showers during a whole month or more. The river, however, is fast rising, no doubt there is a heavy pour up at Bhamo and other places in that direction." The writer availed himself of the aid of the Manager and Agent of the Irrawaddy Flotilla; and their Mandalay Agent Signor Andreino very kindly kept him informed of the height of the river at Mandalay. An Italian engineer, Signor Federici, furnished the mark of the 1875 flood (Mr. Bain having left Mandalay). Signor Andreino says.—"At the end of July the water was at its highest and it was 8 inches higher than that of 1875; it afterwards fell 11 feet. On the 12th August it commenced to rise; and on the 19th it was 5′ 3″ below the 1875 mark. On the 22nd it was 2′ 5″ below; on the 26th 15 inches below, rising eventually to 6 inches below the 1875 flood mark, or about 1′ 2″ below the previous rise in July. The exact date of this is not given; but on the 29th the river had fallen to 1′ 8″ below the 1875 flood mark. Signor Andreino says, Mandalay 1st September "I may remark that below Mandalay there are several affluents which affect a

great deal the rise and fall of the river below. I forget now in what year it was, that on account of the heavy rain on the Arracan Hills the Moo, Chindwin, Yan Mong and Mang were much swollen, so that I went to the Woon's house with a cutter from the steamer, while at Mandalay the river was comparatively low. This year the water rose several inches above the flood of 1875 [at Mandalay] while at Minhla near the Woon's house, it was very little flooded. I hear that the above mentioned creeks have not been very high on account of the very little rain on the hills." On the 22nd September replying to further enquiries by the writer he says "Since then [the last letter] I hear that the affluents and creeks below Mandalay, which are numerous and some considerable have swollen a great deal. This may account for the second flood being higher than the first at Thayetmyo and Henzada."

These remarks show that the lower tributaries and torrent streams of the narrow neck of the Irrawaddy valley, can exercise an important influence on the floods. Probably the year referred to was 1877 when, though at Mandalay the river was lower than in 1875, the flood wave was more acute in the trunk below. It has to be noted that in each case the river at Mandalay was in extreme high flood, a condition which appears indispensable to the formation of a flood in the delta.

One very curious circumstance connected with the formation of the flood waves on the Irrawaddy, and, as far as is known, on all the rivers emerging from the great Thibetan Plateau, is the periodicity of the rise and fall of the larger flood waves of, at any rate, the three months July, August and September, when the highest rise occurs nearly always about the time of full moon. Of course the rise cannot be absolutely synchronous with the lunar period, as on length of the river from Bhamo to Mandalay and Mandalay to Myanoung an amount of time must elapse for the passage of the wave downwards. But the regular recurrence of the greater rises with each full moon is most marked, as well as the singular excess of height which the August flood wave has over the others. In the present year full moon occurred about the beginning and the end of August; the two great waves of the year accompanying them with accustomed regularity. It is fortunate that this permits preparation to be made for each rise beforehand.

The writer has endeavoured to find in meteorological studies an explanation of this phenomenon; but most of the writers quoted in Part II of this Report either consider the moon's influence in such matters to be too doubtful to be formally discussed; or, like Herschell, consider the lunar influence unimportant (1). He asserts that "*the gravitation tide* of the atmosphere, depending on the joint attractions of the sun and moon will give rise to no greater difference of level in the aerial strata than that which the same causes produce in the ocean itself, *viz.*, about 6 feet. Its effect on the barometer therefore, would amount at the maximum to less than 1—130th of an inch." He, however, in discussing the effects of the diurnal heat tides shows that the indirect effects of such tidal oscillations of the atmosphere are 7000 times greater than the direct. Such indirect influence might cause a monthly tide in the atmosphere, of sufficient disturbing power to loosen or cause a precipitation of the large masses of vapour accumulated by solar influence in the region of the monsoons.

M. Ad. Quetelet (2) investigated the influence of the moon on the barometric pressure from 1833 to 1847, and found that there are three maxima and three minima of pressure, the maxima falling about the 6th, 16th, and about the 24th days of each moon; while the minima fall midway between. He says "This concordance, very little sensible, is meanwhile sufficiently marked to be recognised. In discussing the observations of Schluber and Flangergues, Arago found that the rain falls more frequently and that the barometer is lower during the second octant than at any other epochs of the lunar month; and finally that the least chances of rain and of the greater barometric elevations occur towards the last quarter and the fourth octant."

(1).—Herschell Sir John F. W. Meteorology 1861 to 1871
(2).—Quetelet M. Ad. Meteorologie de la Belgique 1867, p. 73.

Possibly these influences would be more marked in the tropical and sub-tropical latitudes than in northern Europe, and were attention directed to the subject by the numerous observers who have means for recording and studying at hand, some light might be thrown upon the matter; which is one of high interest, especially in discussing and dealing practically with the floods of rivers like the Irrawaddy. The periodicity of the flood rise is traceable throughout the year but in the other months than those of highest flood there are several interfering influences.

The heights attained by the two great flood waves of 1879, in the Irrawaddy delta and on the Nawoon river, are given in the accompanying table 21 A, together with the heights of the previous great floods of 1875 and 1877. The double rise during this year to heights above the flood of 1875 necessitates the dropping out of the category of great floods such rises as those of 1868 and 1871, which at the time they occurred were beyond anything upon record.

Table No. 21 A.

STATIONS.	IRRAWADDY RIVER.			
	Distance.	Flood heights above M. S. Level.		
		1875.	1877.	1879.
				1st Rise.
Saiktha	0	77·86	79·74	77·78
Myanoung	15·5	70·91	71·87	71·16
Kanoung	22·7	68·07	...	68·10
Shwe-gyeen	35·	61·34	62·09	61·17
Nyoungyo	51·	53·77	54·10	53·44
Loodauzoo	63·5	(50·00)?	...	...
Nawoon	72·0	45·7	...	45·20
Henzada	84·	43·48	43·78	43·13
Zaloon	101·	35·99	36·41	35·16
Donabyoo	130·	24·47	24·43	24·17
Setkaw	144·	19·00	...	..
Baudee	165·	10·99	...	...
Nawoon River.				
Thambyading	0	48·00	48·36	...
Nawoon	4	45·70	46·10	45·20
Myogwin	8	43·20	44·26	42·90
Leymyethna	30¼	33·91	35·41	34·24
Zimbyogong	42¾	30·11	31·86	30·63
Ngathaingyoung	64½	24·29	26·62	26·62
Maygeelaha	87	17·42	21·51	22·68
Zeebingwin	98	13·36	14·98	15·86
Taboo	107½	...	10·62 ?	9·45
Shoaynyoungbin	116	...	9·47 ?	...
Daga mouth	127	...	8·56 ?	...

The first of the 1879 flood waves as before stated rose 8 inches higher at Mandalay than the 1875 high flood mark; and is thus, if the statement is accurate, the highest upon record at that place. At Thayetmyo the same wave stood 0·32 feet above the 1875 mark, and 1·88 feet below the 1877 mark. It maintained this position intermediate between the two floods as far south as Nyoungyo; but at and below this station it stood a few inches lower on the Irrawaddy than the 1875 mark.

The second wave which was 14 inches lower at Mandalay than the first, rose 0·88 feet higher at Thayetmyo, 0·25 feet at Myanoung, and 0·15 feet at Henzada. It is curious to note that the Nyoungyo gauge reads lower on both occasions than in 1875; and what is still more remarkable the second wave is 0·67 feet lower than the first. This is due to the fact that the Irrawaddy has made a decided set at the bank in the neighbourhood of the gauge; from one to two hundred feet of the bank having been cut away during the flood season of 1879, so as to necessitate the removal of the inspection house. A large mass of bank was lost between the two flood rises.

One breach occurred on the Myanoung Embankment. This happened before the flood was very high, and was solely due to the negligence of the subordinate officer in charge, to whom a leak in the ground was reported at 4 P. M. by the watchman, and who did not visit the spot till the next day, when it was too late to control it. This was on the 29th mile. No damage resulted to the crops. The Overseer has been ordered to resign as a punishment. All the other works resisted the strain successfully.

Irrawaddy Gauge Readings kept at Myanoung for the year 1878-79.

Date.	1878. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	1879. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Date.
	Ft. De.	Ft. De.	Ft. De.																						
1	4·71	2·46	2·54	3·56	4·08	5·06	21·19	36·02	31·58	35·75	22·17	10·50	5·33	2·58	1·46	4·08	1·00	6·25	34·83	40·25	40·50	32·50	27·83	8·33	1
2	4·60	2·38	2·38	3·38	3·93	5·31	22·60	36·35	32·02	35·83	21·83	10·25	5·25	2·58	1·42	3·50	1·00	6·17	34·92	40·08	40·33	31·25	26·92	8·19	2
3	4·50	2·25	2·44	3·13	3·73	5·77	23·56	36·54	32·42	35·83	20·33	9·96	5·08	2·50	1·37	3·00	1·00	6·08	35·08	39·83	40·00	28·50	26·67	8·92	3
4	4·40	2·19	2·98	2·94	3·68	6·08	24·48	36·73	32·75	34·62	19·42	9·79	4·92	2·50	1·33	2·58	1·00	8·25	35·25	39·29	39·75	27·67	26·00	7·83	4
5	4·31	2·10	4·08	2·77	3·62	6·04	25·17	36·77	33·42	34·25	18·50	9·54	4·83	2·42	1·29	2·33	1·83	12·50	35·33	38·42	39·42	27·08	24·58	7·71	5
6	4·21	1·98	4·88	2·69	3·50	5·75	25·89	36·77	33·83	33·50	17·75	9·25	4·75	2·42	1·25	2·16	2·92	16·25	35·33	37·58	38·83	26·33	22·75	7·54	6
7	4·06	1·90	4·92	2·65	3·42	5·33	26·58	36·60	34·17	32·42	17·17	8·96	4·67	2·33	1·21	1·92	3·50	19·75	35·25	36·75	38·33	26·25	20·67	7·29	7
8	4·02	1·85	4·60	3·02	3·42	5·06	27·35	36·44	34·44	30·92	16·67	8·76	4·58	2·33	1·17	1·88	3·58	21·83	35·17	36·25	37·17	25·92	18·92	7·17	8
9	3·98	1·75	4·31	3·79	3·48	4·75	28·16	36·19	34·50	30·21	16·42	8·50	4·42	2·25	1·13	1·79	3·33	23·50	35·08	35·92	35·92	24·25	17·42	7·13	9
10	4·04	1·77	4·21	4·48	3·38	4·42	28·73	35·96	35·96	29·83	16·42	8·33	4·33	2·25	1·08	1·75	2·92	25·17	35·17	36·00	34·75	23·50	16·33	6·92	10
11	4·38	1·77	4·40	4·71	3·23	4·19	29·73	35·69	35·69	29·58	16·25	8·17	4·25	2·17	1·04	1·70	2·71	26·25	35·17	35·88	33·42	22·92	15·42	6·87	11
12	4·79	1·79	4·54	4·67	3·15	5·04	30·35	35·60	35·60	29·83	16·33	7·92	4·25	2·17	1·00	1·83	2·46	27·50	35·13	35·50	31·57	22·42	14·75	6·67	12
13	5·00	1·63	4·48	4·92	3·13	5·04	31·00	35·19	35·19	30·79	16·50	7·75	4·17	2·08	1·00	1·92	2·38	28·33	34·83	34·96	31·57	22·17	14·17	6·50	13
14	4·96	1·54	4·17	5·60	3·54	6·25	31·71	34·85	34·85	30·37	16·58	7·67	4·08	2·08	1·00	1·88	2·38	29·08	34·75	34·42	32·75	22·08	13·67	6·62	14
15	4·58	1·42	3·79	6·38	4·08	8·25	32·10	34·83	34·83	32·37	16·83	7·58	3·92	2·00	1·00	1·83	2·50	29·58	34·67	34·20	33·92	22·08	13·17	6·25	15
16	4·27	1·31	3·56	6·44	4·44	9·29	32·35	35·17	35·17	35·88	16·58	7·50	3·83	2·00	1·17	1·75	2·62	29·92	34·83	33·92	34·75	22·17	12·58	6·21	16
17	4·00	1·21	3·17	6·96	4·44	9·92	32·69	35·56	35·98	36·25	16·67	7·33	3·75	1·92	1·25	1·70	2·62	29·92	35·33	34·11	35·42	21·92	12·08	6·08	17
18	3·75	1·13	2·96	6·70	4·50	10·33	32·89	35·88	35·88	36·17	16·92	6·92	3·67	1·92	1·33	1·77	2·79	29·83	35·83	34·42	35·92	21·33	11·67	6·00	18
19	3·58	1·08	2·75	6·46	4·50	10·19	33·10	35·92	35·92	35·83	17·75	6·83	3·58	1·83	1·42	1·62	2·75	29·58	36·25	34·83	36·57	20·83	11·33	6·00	19
20	3·44	1·13	2·58	6·44	10·83	10·13	33·23	35·85	35·85	35·50	17·58	6·67	3·50	1·83	1·46	1·58	3·67	29·50	36·42	35·33	36·75	20·50	11·08	5·92	20
21	3·31	1·25	2·46	6·38	9·58	10·19	33·35	35·35	35·33	34·75	16·92	6·58	3·42	1·75	1·50	1·54	4·75	29·75	36·83	35·79	36·92	20·83	10·75	5·83	21
22	3·19	1·65	2·31	6·21	7·36	9·94	33·42	34·67	34·67	33·79	16·17	6·50	3·33	1·75	1·50	1·54	5·46	30·33	37·17	36·33	37·42	21·92	10·42	5·83	22
23	3·08	2·40	2·17	5·94	5·70	9·83	33·46	34·02	34·02	32·58	15·33	6·37	3·17	1·67	1·58	1·62	5·75	31·08	37·33	36·75	37·25	23·00	10·17	5·67	23
24	2·98	3·13	2·02	5·67	5·33	10·00	33·58	33·64	35·02	31·25	14·25	6·25	3·17	1·67	2·67	1·77	5·67	31·92	37·75	37·25	36·92	23·50	9·92	5·50	24
25	2·88	3·38	1·98	5·60	5·25	10·90	33·73	33·44	34·54	29·83	13·42	6·08	3·08	1·58	3·08	1·70	5·62	32·67	38·21	37·83	36·75	23·58	9·67	5·42	25
26	2·83	3·25	2·08	5·69	5·64	13·21	33·96	33·31	34·25	28·33	12·67	5·92	2·92	1·58	4·33	1·45	5·92	33·25	38·58	38·33	35·25	23·92	9·42	5·25	26
27	2·77	3·00	2·27	5·60	5·21	15·86	34·17	33·10	34·23	26·58	12·17	5·83	2·92	1·50	5·58	1·20	6·54	33·75	39·00	38·83	35·00	23·83	9·17	5·08	27
28	2·75	2·73	2·52	5·27	5·20	17·33	34·52	32·64	34·37	25·25	11·67	5·75	2·83	1·50	6·00	1·00	7·08	34·08	39·54	39·42	33·92	23·42	8·92	4·92	28
29	2·75	...	2·81	4·77	5·23	18·62	34·85	32·17	34·88	23·92	11·25	5·62	2·83	...	5·75	0·91	7·33	34·42	39·83	40·00	33·00	24·33	8·67	4·83	29
30	2·69	...	3·23	4·40	5·25	19·77	35·23	31·79	35·29	22·83	10·92	5·50	2·75	...	5·33	0·91	7·25	34·67	40·17	40·17	32·25	25·83	8·50	4·75	30
31	2·60	...	3·54	...	5·13	...	35·58	31·52	...	..	...	5·46	2·67	...	4·75	...	6·92	...	40·25	40·25	...	28·33	...	4·67	31

Table (A.)

Shewing measurements between Myanoung Embankment and bank of Irrawaddy Main Channel in 1871, 75, 77 and 1879.

Embankment Mile.	Distances. In 1871.	In 1875.	April 1877.	November 1877.	In January 1879.	December 1879.
4 ½	585	547	537	513	515	475
¾	474	330	...	268	250	242
5	603	450	425	312	290	238
¼	650	580	540	441	405	346
½	635	612	605	565	560	507
¾	746	648	645	627	620	606
6	...	...	...	...	653	640
¼	...	...	...	...	630	595
½	...	...	...	..	700	606
9 ¼	979	979	967	970	..	950
½	1078	1010	...	...	1305	896
¾	1005	995	995	...	1145	...
10	794	794	793	786	849	778
¼	589	554	555	525	514	498
½	544	522	500	465	443	409
¾	682	606	580	519	485	437
11	592	533	520	460	635	394
¼	652	650	530	499	492	420
½	929	829	...	816	635	740
¾	798	769	...	717	829	815
22 ¾	950	942	940	920	920	950
23	993	993	970	940	932	952
¼	1073	1052	1050	...	755	945
½	985	980	960	..	802	890
¾	924	919	902	896	890	...
24	956	950	940	914	895	923
¼	999	995	910	901	845	820
½	922	918	840	823	...	810
¾	854	842	800	784	796	730
25	948	923	882	862	820	690
¼	983	973	960	937	908	801
½	1003	992	960	964	915	810
¾	1009	1000	...	947	...	...
¾	1073	1010	980	1000	910	875

Embankment Mile.	Distances. In 1871.	In 1875.	April 1877.	November 1877.	In January 1879.	In December 1879.
34	444	436	410	424	420	380
¼	382	365	354	370	367	350
½	912	...	700	688	697	465
¾	1050	1000	...	969	1000	870
35	1063	...	...	1070	1070	1010
¼	1272	1164	1135	1154	1137	782
½	1124	1292	1164	1155	1155	1120
¾	946	1124	1145	1084	880	630
36	918	910	910	964	851	450
¼	906	918	910	951	790	498
½	732	...	648	754	725	665
¾	696	652	647	654	650	534
37	792	674	655	667	660	662
¼	695	615	595	594	525	660
½	357	274	265	261	239	206
¾	285	216	208	185	140	115
38	481	360	334	303	260	145
¼	496	369	333	310	284	90
½	538	497	476	450	384	160
¾	762	652	642	630	597	365
39	1341	1145	...	1110	1076	551

REPORT

ON THE

IRRAWADDY RIVER

PART III

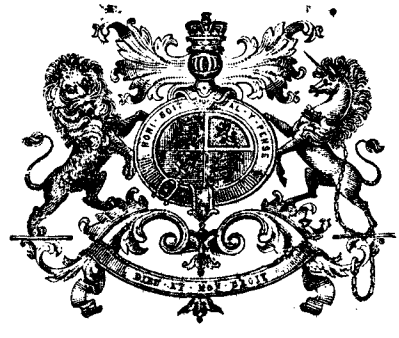
Hydraulics of the Irrawaddy

WITH APPENDICES

and Supplement D

BY

R. GORDON, ESQUIRE, M. I. C. E., AND M. I. M. E.



RANGOON.

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1879.

REPORT

ON THE

IRRAWADDY RIVER

PART IV

The Hydraulic Works

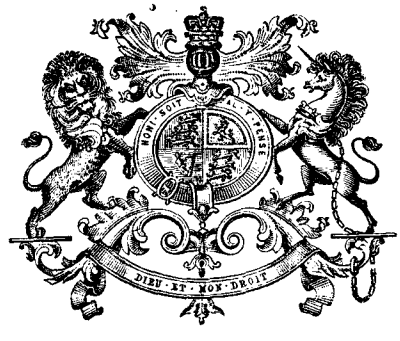
CONNECTED WITH

The Rawoon River

WITH APPENDICES

BY

R. GORDON ESQUIRE, M. I. C. E. AND M. I. M. E.



RANGOON.

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1880.

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PART IV.

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PART IV.

SECTION I.

The Upper Watersheds of the Nawoon.

The Myanoung Plain and its proposed reclamation.

1. The Myanoung Plain has been estimated in the preceding part of this Report to contain about 530 square miles. It is about 40 miles in length from north to south with an average width of 14 miles. Its boundaries are precisely defined on the north and east by the Patashin and Irrawaddy Rivers, and on the south by the first 11 miles of the Nawoon River embankment; but to the west a somewhat arbitrary limit has been chosen where the higher ground skirting the base of the Aracan Yomas meets it in its northern parts, and in its southern by the lower course of the Okpho torrent streams. These western boundaries, as well as the southern ones, may be made to vary, as they are included or not, in the field of projected works, but any departure from them will be noticed.

Natural state of the Plain.

2. In its natural state this area received, besides its own rainfall, the whole discharge of the Mamya torrent, which enters it on its western side about midway of its length, as well as spill waters from the Patashin, from the Irrawaddy, and from the Okpho torrent. Formerly, there is reason to suppose, the whole of these waters, or almost the whole, found their way into the Irrawaddy through the Sinpong, the Noukmee and other smaller drainage streams. The executed and projected reclamation works are intended to wholly exclude the Patashin and Irrawaddy spill waters; to divert and control the Mamya and Okpho torrents; and to regulate and conduct to the Nawoon River all drainage of the Myanoung Plain, from whatever source it comes, in such a manner as to leave the greater part of the area available for cultivation.

Testimony of the Fitzroy and Edgcome Gazetteer.

3. The condition of this plain and its various in-flowing and out-flowing streams, antecedent to the commencement of the protective works now in existence, may be gathered from the Fitzroy and Edgcome Gazetteer; which briefly notices the principal features. The plain is divided into three townships:—Myanoung, Kanoung, and Okpho. The first lies to the north; it is of small extent within the plain, but includes a larger area beyond the boundaries. The portion within the plain occupies the upper end of the shallow saucer-like depression of the plain; and the higher parts both near the Irrawaddy and skirting the hills were fairly cultivated, but were always liable to submersion in the very high rises of the river. The Kanoung township occupies the centre of the length of the plain. Each township is divided into circles under separate native Revenue Officers. The Thabyoo circle is described as follows:—"The general aspect of the country is low, and it is subject to inundation during the rains, there is, however, a small patch of rice cultivation." "The Akyau circle has the whole area covered with grass-jungle and trees, and the country is low and inundated during the rains." Similar statements are made of other circles occupying this central township. The Okpho township includes the whole lower part of the plain. Almost identical words are used of the several circles, which consist of low ground subject to inundation in the rains. A considerable extent of cultivation existed from remote times on the right bank of the Okpho torrent; but those words are still fairly descriptive of all the circles lying in the lower part of the Myanoung plain.

4. The action of the Mamya choung and the bad drainage system of the plain cannot be better given than as it is in this Gazetteer. Mamya choung :—"This stream has its source in the Aracan Range, its course has an easterly direction for the first 16 or 20 miles, it is then deflected to the southeast towards the village of Matoungda, but * * * it is again deflected and most abruptly, its direction being almost due north until it falls into the Too Eng or Lake." Of the Too Eng, formerly the largest lake in Burma, but now in a great measure dried up through the embankments, it is said :—"The Too Eng is bounded on the north and west by low hills; trickling down from these numerous small springs keep up the supply of water, which is augmented during the rains by the Mamya choung with the drainage from the Aracan Hills, and also by the water of the Irrawaddy River which enters through the numerous channels that exist east of the lake, and in the dry weather some of these streams form a channel by which this Eng is drained. The banks are low and marshy and afford evidence of this Lake having formerly been larger, but owing to the deposits of the Mamya choung it is being gradually silted up." Of one, the principal of the drainage streams, it is said :—"The Sinpong choung takes its rise in the overflow of the Too Lake; it is navigable for boats in the rains, but its course is much obstructed by grass and other obstacles; the country through which it flows is swampy." The Noukmee or Nayzing choung is said to "change its name after running a mile north of Thayetbinday, it is about 150 feet wide and the depth varies from 3 to 15 feet. It joins the Irrawaddy River at Noukmee. The banks are lined with tree jungle and grass." The Sinpong and the Noukmee unite by various cross streams in the rains; but at present the dry weather discharge from the Mamya and the Too Eng finds its way through the Noukmee choung to the Irrawaddy at Noukmee. The Sinpong also receives the Okpho torrent stream a few miles to the south-east of Okpho. Of this stream all that the old Gazetteer says is the "Kanyeng or Okpho choung has its source in the Arakan mountains, it empties itself into the Bassein River at the village of Songong, sending off a branch called the Thambyading choung into the Irrawaddy River. Although without water in the dry season, during the rains the Kanyeng choung is available for the purpose of floating timber and bamboos." Several other streams and lakes are described in brief terms. One lake the Bootgyee is said to have been "formerly the bed of the Irrawaddy River." "It receives its supply of water not only from the rains but from the Irrawaddy."

The Mamya choung.

The Sinpong choung.

The Noukmee choung.

The Kanyeng or Okpho choung.

5. As far as can be gathered from the Gazetteer the country previous to 1862 was, from Kanoung southwards, entirely inundated during the rains; with the exception of a few places cultivated on the river bank and on the high ground near the hills to the west. The only advantage derived from this area was the revenue of the fisheries in the several lakes and streams, and a small extent of miscellaneous dry weather cultivation. The measures taken to redeem this area from the inundation lying upon it every year have been already recounted; but may again be briefly noticed. From 1862 to 1864 a flank line of embankment was run from the high land south of the Patashin to the Irrawaddy, along which it turned to meet the high land between Myanoung and Kanoung. This completely excluded the Patashin flood waters; and also the Irrawaddy floods to near Kanoung. From 1865 to 1868 the protective embankment was extended to a continuous length of 44¼ miles, stopping abruptly at the village of Loodauzoo; but it was resumed at the 55½ miles to the south of the town of Thambyading, and continued to the north bank of the Nawoon. A commencement was made on the intermediate portion of the work from the 44¼th to the 55½th miles; as it was intended to have one unbroken line of embankment from the Patashin to Pantanaw 130 miles to the south; but the threatened erosion of the Irrawaddy bank from Thambyading to Loodauzoo caused the work on the 44—50½ miles

Former works for the reclamation of the plain.

The Myanoung Embankment.

to be suspended. No attempt was made to close either the Thambyading or the Nawoon River entrance.

The flood heights and slope of the Myanoung Plain.

6. The Myanoung Plain with the works relating to its reclamation are shown in Plate XXI. Figure 1 gives a small scale of plan of the plain itself, with the principal towns and land marks, as well as the neighbouring country and torrent streams. The embankment as it now exists is shown in continuous lines; that portion, the 1st to the 43¾ mile, in one heavy line is entirely completed; and has been well raised above the 1877 flood height; the double line marks the portion roughly executed in 1868, and only raised high enough to meet the uncertain flood height marked previous to that year; the dotted line shows the probable course of the work when finally completed. Figure 2 gives the levels of the embankment, with the heights, relative to mean sea level (to be referred to henceforth as + M. S. L.), of the ground on the site; of the embankment; and of the 1875 and 1871 floods from Patashin to the Nawoon. The heights of the various floods (+ M. S. L.) at the principal points of this line are given in Table 32 below.

Table 32.

	1868.	1871.	1875.	1877.
Myanoung	68·47	70·15	70·91	71·87
Kanoung	66·19	67·23	68·07	...
Shwe-gyeen	59·55	60·50	61·34	62·09
Nyoungyo	52·07	53·77 (?)	53·77	54·10
Loodauzoo	...	49·02 (?)	50·00 (?)	...
Thambyadeing	...	47·00 (?)	...	...
Nawoon	...	44·76	45·7	46·10
Myogwin or Songong	...	41·46	43·20	44·26

All these heights except those at Loodauzoo were marked immediately after the floods by permanent masonry bench marks mostly still existing. There is some doubt as to the accuracy of the marks of 1871 for Nyoungyo, Loodauzoo and Thambyading; as breaches occurred in the embankment near those parts and prevented due attention being given to the marks at once. The errors can only be of slight amount, and, as the great changes in the river channel occurring since that date have brought with them slight changes in the levels in this neighbourhood, the figures given will be taken as sufficiently accurate for present purposes.

Cross levels of the Myanoung Plain.

7. Several series of levels across and through the interior plain country have at various times been taken and connected with these flood marks. A selection from these has been made and arranged in Figure 3, Plate XXI, to show the general shape and configuration of the country, and at the same time to give a conception of the effect of the various works executed or proposed, in lowering the surface of the inundation during the higher floods. Four lines of levels are given; and are drawn on a scale to show the relative heights above mean sea level (+ M. S. L.), so that the general fall of the country may be easily perceived. The first line runs from the Kanoung bench mark in a direction nearly due west towards the hills; and terminates on the rising ground at a level somewhat above that of the Irrawaddy floods at Kanoung. The second line starts from Shwe-gyeen, at the 25½th mile of the embankment, and follows a cart road nearly due west till it crosses the Mamya choung (choung=stream) shortly above its entrance into the Too Lake. It follows the bank till it reaches a higher level than the flood mark at Shwe-gyeen. At Nyoungyo the third line was taken from the bench mark for

a mile or so southwards along the embankment before it found a suitable place to penetrate through the forest towards the hills. This portion of the line has been omitted and only the levels of the country are shown. The line emerges from the forest near Thakaybin on the Okpho choung, and terminates at a point where the level of the starting height is reached. The fourth line commences at the village of Noukmee or Noukmyee, at the mouth of the creek of that name, and crosses nearly west to the Okpho choung, meeting it at a place where the Wutta choung bifurcates from it. The line follows the bank of the Okpho creek to the town, then crosses into lower land beyond, which is inundated in floods; where it terminates.

Configuration of the Plain.

8. These four cross sections show that the general level of the country is from 5 to 10 feet below that of the river bank; and that the fall from the river towards the interior is always completed in the first mile. By the arrangement made of the levels in figure 3, where the whole of the outlines are given from a common datum line, the effect of excluding the river floods from the country by the embankment, assumed as terminated at the different stations, can be readily perceived. In the figure only one flood line, that of 1871, is given at each station in order not to confuse the drawing. A horizontal line is drawn at the height marked by the 1871 flood at some of the principal places named in Table 32. The 1871 flood is chosen as a reference line as it was more perfectly and more extensively marked than that of 1868 on the one hand; and on the other it is preferable, in considering drainage questions, not to take the extreme high floods like those of 1875 and 1877, which have principally to be considered with reference to the embankments, but whose short duration and unfrequent recurrence cause but little hindrance to the drainage compared with the more regular ones. The 1871 flood stands midway between ordinary and extreme high floods; and it represents the most useful limit at which the outfall levels may be taken for the various points where the interior drainage would be delivered if the embankment were abruptly terminated at them.

Selection of the 1871 flood as the reference datum for the reclamation works.

The 1871 flood at the different outfalls.

9. Had this flood occurred when the embankment only reached Kanoung it is evident since the country on the line there (See Figure 3, Plate XXI) lies between 56 and 67 feet (+ M. S. L.); while the flood reached to 67·23 feet, that the interior would have been entirely submerged. The water would even have penetrated to behind Myanoung. The continuation of the embankment to Shwe-gyeen would have thrown the outfall level of the 1871 flood to 60·50 (+ M. S. L.) feet. The plain there lies between 51 and 60 feet, so that there could have been no dry land between the river bank and the base of the hills. The water would have also passed round the end and in the rear of the work as far north as Kanoung, where all the land below 60½ feet would have been submerged. Similarly the extension of the work to Nyoungyo with its 1871 flood level of 53·77 feet (+ M. S. L.) would have left unprotected the country not only behind that place but west of Shwe-gyeen. As a matter of fact the work was extended to Loodauzoo, where the level was noted at 49·02 feet (+ M. S. L.), (more probably nearly 50 feet), and the inundation was found much further north than Shwe-gyeen where some of the low lands were submerged. But these results were complicated by the discharge from the Mamya torrent which causes the Too Lake to overflow, and by the inflow from a breach at the 18th mile of the embankment, as well as by the natural drainage of the plain finding great difficulty to flow away through being backed up by the great height of the water at Loodauzoo. It is at present very difficult to proportion the effects derived from the different causes.

Effect of the retention of the Loodauzoo outfall.

10. Even if the discharges from the Mamya and through the breach were removed the retention of the Loodauzoo outfall must exercise a pernicious influence on the natural drainage in a flood height like that of 1871. Two large drainage creeks are shown on the Shwe-gyeen Section line. Both communi-

cate with the Noukmee choung, and they are the principal drainage channels to the country north and west of them. The bottom of the one marks 28·61 feet (+ M. S. L.), of the other 31·84 feet. Their banks are at about 51½ and 54 feet (+ M. S. L.). The water standing at between 49 and 50 feet at Loodauzoo holds back all water in these creeks below that height; and in order to get a sufficient surface fall to make it travel the 20 miles southwards to Loodauzoo the drainage water has to rise out of the channels of both creeks and inundate the surrounding country. The height of the Irrawaddy at the present embankment end at Loodauzoo thus regulates the whole system of the interior drainage channels by which the rainfall is removed to the river. Experience has proved that the Loodauzoo outfall is far too high to permit the greater part of the country to be reclaimed; and the expenditure of Rs. 9,85,000 on the Myanoung Embankment has hitherto proved unremunerative from this cause, when tested by the amount of land revenue allotted to the work as a return for the outlay.

Colonel Short's plan considered.

11. The original scheme of Colonel Short provides the very best means of removing all difficulty about the outfall. He intended to sever entirely all connection between the Irrawaddy and Nawoon Rivers by closing the Thambyading and Nawoon openings and by making the Myanoung Embanment continuous with the Henzada one. All ingress of the Irrawaddy floods to the plain would thus have been prevented; and the capacious channel of the Nawoon River would be available to receive the drainage from the Plain. The outfall level would be reduced to the lowest possible point. What that would be can only be known from actual experience. If the hill waters could be satisfactorily disposed of it is probable that the natural drainage channels, with comparatively slight improvements, would convey all the rainfall away. There are, unfortunately, insuperable obstacles existing to the execution of Colonel Short's plans in their entirety.

Certain measures recommended.

12. The interruption to the execution of the continuous embankment was brought about in 1868 by the threatened attack of the Irrawaddy round the western and northern front of the Thambyading bend under the circumstances detailed in the preceding part of this Report. As shown in Plate XIX, a large portion of the bank on which it was then designed to carry the work has since been carried away, and parts of the embankment itself are now yearly falling into the river. The writer has steadfastly recommended that all attempts to continue the embankment should be suspended until this action of the river channel upon the bank at that place should cease entirely, or so far as to permit the work to be carried on the newly formed and elevated bank. The reasons for this recommendation will be more fully detailed in the present section. They are based on more objections than that derived from the cutting away of the bank, as will presently appear, but it may be said that these are all at present in course of removal, and the writer would now as strongly recommend certain measures being put in hand as soon as practicable as he has hitherto urged their being deferred. Designs and estimates are accordingly given for the particular works which it is considered expedient to carry out at once, while the whole scheme will be discussed generally and such alterative projects as are recommended for future consideration will be pointed out, with the reasons having weight in each particular case.

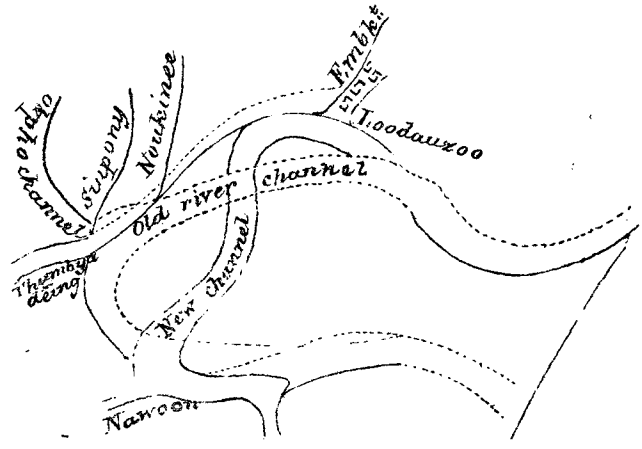
Further examinations of the Thambyading Bend.

13. The writer has again lately personally examined the country and the changes in progress on the western side of the Thambyading bend. It seems unnecessary to give detailed plans of these changes as they are still in progress, and the channel has not reached a permanent régime. Generally stated they may be said to consist of a development of the smaller curves into which the pointed end of the former horseshoe bend has changed. Two such curves are shown in the plan for 1877 (Plate XIX); the one travel-

ling to the north-east the other to the south-west, the convexity of each turned outward. Both these curves have increased in diameter, and their rate of travel appears slower, though they still move in their original directions. Another curve of contrary direction now joins them, and this also yearly increases in diameter, but appears stationary in position.

Development of curves in the bend.

14. The upper or Loodauzoo curve has swept on in its course along the bank from Thambyading past Noukmee, slicing off several hundreds of feet of solid earth. The action has now entirely left the lower four of the six miles intervening between the embankment end and the entrance of the Thambyading choung; and the water passing over has already raised the new edge almost to the height of the old one. These four miles of bank are quite ready to receive the embankment, which will be in this part one of the cheapest and safest portions of work in the whole system. Levels were taken on the site of the proposed line of work in 1877; and showed that a five or six foot high embankment would suffice at that time. Since then the bank has been still more raised and consolidated, thus still further facilitating the execution of the work. The levels referred to are given in Figure 4, Plate XXI.



Changes in the ground.

15. When these levels were taken a considerable portion of bank intervened between the river and a large lake or depression in the ground to the south-west of the end of the present embankment. The erosive action of the Loodauzoo curve removed the whole of this higher ground in the years 1877 and 1878, and exposed the bed of the Lake, which lay some 20 or 30 feet below high flood level. The counter action of the water has not only raised the ordinary bank of the river in the low plain ground, but has made an enormous deposit in the lake itself, where the alluvion now lies in an immense mass sloping gently from the river to the interior. When the Loodauzoo curve first touched the embankment in 1876, it cut off more than a thousand lineal feet from the end of it, but as the front of the curve passed further on this action lessened, and measurements made on the 28th May 1878, and in January 1879 show that only 260 feet were lost in the interval. There is thus a great diminution in the intensity of the erosion; and, when once the centre of the curve front has passed, the action will still further lessen and finally disappear. So far as can be judged on this most difficult point the erosion has now reached this last stage of its progress; and though there will still be some erosion for the next year or two, this will be more than compensated for by the continuous elevation of the present low bank which goes on at the same part. The line of levels referred to above passed over a part of the bank which has now disappeared in the river for nearly two miles. The ground then ranged at heights (+ M. S. L.) of from 40 to 43 feet; while the 1871 flood height lies between 48 and 50 (+ M. S. L.) feet. The 1877 flood is higher; and the height of embankment required would have been generally from 12 to 15 feet. By the land-raising action of the river all the ground on which the future work will be laid will be raised in a year or two to at least 45 to 47 feet (+ M. S. L.), leaving only 6 feet to be met by the new work. Already several feet of this natural embankment have been constructed and the progress made is most satisfactory. There was, in the well grounded anticipations of this process operating, a strong reason to wait for the cessation of the river action in this neighbourhood before extending the embankment works.

16. There is nothing now to hinder four out of the six miles of the work required being done at once; that is, the miles marked from 46 to 50 on the plans. From 44 to 46 will have to be left for a short period, probably two years; and by that time the new bank will be ready to receive the work. The cost of this will not be over 5,000 or 6,000 Rupees per mile, or with contingent expenses it will cost Rs. 40,000 for six miles. Detailed plans are not now sent in, but can be prepared in a short time on re-levelling the newly raised bank when it is required to put the work in hand. In any case, this is an indispensable portion of any scheme for improving the interior lands; an item of Rs. 40,000 (£4,000) must be carried to account as a first step in the operations. This work is numbered Project No. I. Section I.

The continuation of the Myanoung Embankment to Thambyading. Project No. I Section I.

17. The embankment now described is an indispensable part of all schemes for the protection or improvement of the interior plains; but it forms a comparitively insignificant item in the cost of the various works required before that reclamation can be completed. Simultaneously with the execution of this embankment a cut must be made to divert the drainage at present issuing by the Noukmee into the Irrawaddy, from that stream to the Nawoon River by the Sinpong. The dry weather discharge from the Mamya torrent, as well as a great portion of its flood waters pass through the Noukmee after flowing through the Too Lake. It is intended to divert entirely the Mamya from the low plain land, so that the Noukmee discharge will be considerably lessened. Its burden has already been diminished from former requirements owing to the stopping of the numerous streams which used to flow into it from the Irrawaddy; but the universally flooded state of the country along its whole length prevents all attempt to ascertain the relation between the capacity of its present channel and its probable requirements. It is known, however, that it already communicates by small channels with the Sinpong, and during high flood the two streams are lost in the great inundation spread over the country, which moves slowly in the direction of the Nawoon River. When this inundation is reduced by extending the embankment this promiscuous communication of the two streams can no longer have place. It is hoped and intended that each shall flow well within its banks, even in high floods; and the great reduction of the amount of water to be discharged makes it reasonable to expect that the one stream the Sinpong may be found adequate to carrying in the lower part of its course the whole of the drainage of the Myanoung Plain.

Proposed cut from the Noukmee to the Sinpong choung. Project No. II.

18. It has been proposed to close the Noukmee choung by the dam carrying the embankment, and to leave the water to find its way over or through the banks to the Sinpong, relying on the cross channels known to exist between the two. But, on examination, the only channels the writer found are of small size compared with either of those creeks, and from their shallowness and obstructed state cannot be expected, without great expense for clearing and deepening, to carry away speedily the drainage from the Noukmee. The writer therefore recommends that a clear cut be made between the two, the only determining condition being that the shortest distance be chosen. A line has accordingly been selected starting from a point about a mile above the village of Noukmee on the creek of that name and running at an angle of 260° to the Sinpong, which it joins in a favorable position. The length of the line is 5,200 feet. The Noukmee has a width of 170 feet between the banks, with a depth of 25 feet. Its area is 1,930 square feet. The Sinpong has a width of 184 feet and depth of 22 feet; while its area of cross section is 2,175 square feet. The heights given in figure 5 are + M. S. L. There is very little water in the Sinpong choung, only about 18 inches in depth in the dry season; while the Noukmee has over five feet with a continuous flow in it. Both bed and banks of the Noukmee are higher than those of the Sinpong; the former standing at 45·68 and 21·09 feet (+ M. S. L.) respectively, the latter at 40 and 17·75 feet. In the

Reasons for the proposal.

absence of the exact measurements necessary to determine the size of the proposed cut, the present dimensions of the Noukmee choung at that place are useful; but it has to be remembered that the Mamya, which is 80 feet wide and 23 feet deep with 1,167 square feet cross sectional area, will be excluded from this stream. It will be a liberal but not extravagant area to give to the cut to make it about 1,300 square feet cross section at the entrance from the Noukmee. This size is attained by fixing its bottom at 24 feet (+ M. S. L.), with 20 feet width, and slopes of 2 to 1 on both sides. The top width is 106·5 feet at this part. A fall of 4 feet from the Noukmee to the Sinpong brings its bottom level there to 20 feet (+ M. S. L.) The same bottom width and side slopes are kept throughout. The greatset depth of the cutting is 25·83 feet. It contains 7,086,000 cubic feet of earthwork; which at 1 Rupee per 100 cubic feet will cost 70,860 Rupees; and with contingent expenses it may be taken at Rs. 80,000. This work will be numbered Project No. II. The whole of the details are given in the Appendix, and Figure 4, Plate XXI, contains all that is necessary for the working drawings.

Cost of Noukmee cut.

19. It has often been assumed by those who have officially expressed opinions on the desirability of carrying the Myanoung Plain reclamation to completion, that by continuing the work to Thambyading the greater step would have been taken towards arriving at that end; but this is far from being the case. It is difficult now to fix the height the 1871 flood would take at Thambyading were it to recur; the changes there have been so great. The marks erected at the time have been carried away with the ground upon which they stood; though these were nearly ½ mile away from the river. From the levels since made it is probable that 47 feet (+ M. S. L.) will fairly represent the 1871 flood height; and this has been chosen. A line drawn at that height in Figure 3 shows that the flood, if it stood for any length of time, must penetrate as far north as the Nyoungyo line, where it would meet and back up the higher-level water. From Nyoungyo southwards a large portion of the country would remain under water in ordinary high floods; but by far the larger part of the area now annually submerged would be effectually redeemed in those floods rising four or five feet lower than that of 1871, should the complete exclusion of the hill waters be satisfactorily accomplished. Before turning to this question all the best possible modes of securing the lowest free out-fall for the area must be considered. The great advantage resulting from attaining this will be made manifest.

The Thambyadeing out-fall.

20. The objections now existing to the carrying out of Colonel Short's plan of a continuous embankment closing the Nawoon may be summarised under three heads:—1st:—It is desirable in the general interests of the province to keep open the communication between the Irrawaddy River and the Nawoon as long as possible, as there is considerable intercourse between the Bassein District and the Irrawaddy country which is likely to develope. 2nd:—The Thambyading entrance not only affords the desired communication at present in all seasons; but in floods it and the Nawoon entrance together afford considerable relief to the Irrawaddy in carrying off a portion of the discharge. It would be most inexpedient in view of the changes supervening in the channel at the Thambyading bend, which tend to raise the river surface near Henzada, and having regard to the possible carrying out of the proposed eastern embankment, to shut in to the main channel a large additional quantity of water. 3rd:—The Thambyading river, which has a minimum width of 500 feet and depth of from 70 to 80 feet of channel, contained altogether in a soft alluvion, offers a difficult and expensive task to close artificially, a work which should only be undertaken from reasons of extreme urgency.

Objections to joining the Myanoung to the Henzada Embankment stated.

21. It is possible that within the next few years the Thambyading may close of itself, and its channel become silted up as that of the Nawoon has done; but there is at present little prospect of this. It is an eventuality, however, which must be kept in view and prepared for, as it will change in a considerable measure the plans for securing a low out-fall for the Myanoung Plain. If it is found that nothing but the most expensive works can keep this entrance open, it will be better to allow matters to take their own course. The objections above mentioned will naturally fall to the ground, and the original plans can be carried out. Project No. I would thus be continued, the second section of the work could include the completion of the 5 miles of embankment already partially executed from Thambyading to the Nawoon and the closing of the Thambyading and Nawoon Rivers. No estimate can at present be made of either of these works, as only very extensive changes can justify their being undertaken, and these changes will of course bring with them altered conditions and cost to the work.

Conditional proposals for joining these embankments.

Project No. I, Section II.

22. One change, which a year or two ago seemed the most improbable of all to occur, has commenced to take place. The lower of the two small curves into which the point of the Thambyading bend changed has been travelling in an opposite direction to that of the upper or Loodauzoo curve. It has just reached the Nawoon entrance and is slicing off immense masses of the bank at this place. It has already removed a large sandbank which formerly lay there, and a deep channel occupies its site. The channel of the Nawoon itself had been almost entirely filled with sand at its mouth, so that it was scarcely perceptible from the river except at high flood. The deposits have been carried far down the course of the stream; but diminish rapidly in amount. The cutting action of the front of this Nawoon curve is now removing sufficient of the bank to carry away the dam at the mouth with the heavier deposits If the process goes so far as to reach the deeper part of the channel it might permit the entry of a current strong enough to clear out the course of the stream and render it again available for navigation. It is impossible to predict the actual results. But if the Nawoon were to open sufficiently and the Thambyading to close, the best possible solution of the difficulties with a conciliation of all the conflicting interests would be attained. The navigation would be uninterrupted; the Irrawaddy flood relief would be kept open; and a tolerably low out-fall would be provided; which might be carried still lower by embanking the right bank of the Nawoon to its junction with the Thambyading at Songong.

Changes at the Nawoon entrance.

23. The 1871 flood marked 44·76 feet (+ M. S. L.) at Nawoon, and 41·44 at Songong. This last is the very lowest point to which any drainage or protective works for the improvement of the Myanoung Plain can at present be carried with advantage. The construction of the Nawoon Embankment since 1871 has brought changes with it in the height of the floods at this place; so that the 1871 flood would probably take a different level there now. Using however these figures, it is clear from the levels in Figure 3 that either the Nawoon out-fall or that of Songong would reduce the level of the exterior flood waters below the ground line at Nyoungyo, while the Songong one would barely lower it sufficiently to relieve the country between Noukmee and Okpho from the influence of an 1871 flood in backing up the interior drainage. It must be recollected, however, that such a flood rarely occurs; and that for three out of every four years the high flood level barely reaches within 3 or 4 feet of the 1871 flood height; and that in these years the drainage could flow freely away from almost the whole Myanoung Plain with the Songong out-fall.

The Nawoon and the Songong out-falls.

Nawoon right embankment.

24. The question of providing this outfall has been discussed on the assumption that the Nawoon entrance will become again available for continuous navigation. This contingency is however so remote and improbable that beyond numbering the contemplated embankment of the right side of the Nawoon as Project No. I, Section 3, no further consideration need now be given to it. In the more probable event of the Thambyading remaining open as at present the Songong out-fall can still be secured but at a comparitively great cost. This can only be done by continuing the Myanoung Embankment from the end of Project No. I Section I at Thambyading, along the right bank of that river to Songong, and at the same time diverting the Sinpong drainage stream so that it shall debouch into the Nawoon at Songong. The first embankment work will be numbered Project III; the Sinpong cut will be Project IV.

Project No. I, Section 3.

The Songong cut and embankment.

Projects III and IV.

Project No. III.

25. Ten miles of moderately heavy embankment costing Rs. 10,000 per mile together with a strong dam across the Sinpong will be required for the first work. It is not recommended that this be put in hand for sometime, so that detailed plans and estimates are now unnecessary; but approximately estimated the whole work will cost about Rs. 1,20,000. The diversion of the Sinpong can best be accomplished by enlarging the lower part of the Okpho choung for the first half mile, and then making a straight cut of 3 miles in length to near the village of Kayenzeik on the Thambyading river, from which place it will run parallel to the river for 2½ miles to Songong. As in the case of the Noukmee cut the exact size of the channel suited to the further requirements cannot be determined beforehand from the data available, as the conditions of the drainage will be much changed by the completion of the embankment, and by the amelioration of the torrents. But judged by the size of the present stream it will be expedient to make this cut not less than 80 feet wide at bottom, with side slopes of 2 to 1 on each side, and a probable average depth of 30 feet and top width of 200 feet. The cost of this will be at least 2 lacs of Rupees per mile of excavation (£ 20,000); or for 5½ miles, 11,00,000 Rupees; to which may be added another lac for extra works bringing the total cost to Rs. 12,00,000 (£ 120,000) in all for Project No. IV.

Project No. IV.

Certain projects to be held in abeyance until the results of others are known.

26. The combined Projects III and IV will thus probably cost Rs. 13,20,000 to complete. It is intended that they shall be held entirely in abeyance until not only all the changes now in progress on the Irrawaddy, near the Thambyading bend, shall have been accomplished, but till several other projects have been completed and their results in reclaiming the Myanoung Plain clearly and distinctly determined. Projects I and II with the works for the regulation of the torrents will bring about a certain definite improvement to the Plain, especially in its northern and central parts; and when the extent of this reclamation is accurately known, and the country in course of cultivation, the remaining southern part of the plain which will still be inundated can be measured, and the commercial value of the land weighed against the cost of the necessary works of redemption still to be done. Unless it can be shown that the operation will be profitable, it is unlikely that these projects will be undertaken. If, however, it is found that a financial success is probable, it will be well to execute only half of the works at first; terminating them for the time at Kayenzeik village; where an outfall with an 1871 flood height of 43 or 44 feet (+M. S. L.) may be secured at a probable cost for the works proposed of about Rs. 8,00,000. When the effect of this, which will redeem by far the larger portion of the remaining inundated land is known and measured, the expediency of carrying out the entire work as above may be decided upon.

27. Before proceeding with the consideration of this particular case of reclamation, it will be well to examine the general principles of drainage resulting from experience on similar works with a few cases which present noteworthy features for guidance. It will be difficult to find a more valuable exposition of such principles than is given by Signor Commendatore Lombardini in the Notices of Lombardy (1). The river water having been excluded from the plains by embankments, it becomes necessary to prevent the interior waters from stagnating there. These are conveyed to the lowest attainable part of the river by natural or by artificial channels. The task is the most difficult in the more recent alluvions of the river, since these have not only a slighter slope, but are generally separated from the river by a high bank of silt deposit. When, however, there is sufficient slope in the ground, the drains are encased in embankments and have free out-falls. When the land drained is entirely surrounded with embankments, it is necessary in order to give a ready discharge to the water to take other precautions. Any hill water should be conveyed by separate embanked channels with free out-falls to the river. The waters of the lower plains must be discharged by drains furnished with sluices at the out-falls. The best examples of reclamation by drainage in Higher Italy invariably have the hill waters separated entirely from those of the plains. Where it is necessary, the torrential waters are carried in elevated canals passing by aqueducts over the lower drains.

General principles of reclamation by drainage, and examples.

Signor Lombardini's statement of them

28. The principal drains lead the water to the river and themselves receive secondary drains also furnished with sluices. Those at the principal out-falls are called master sluices, some of them being about 30 feet in height. Guards are appointed for the sluice gates, the larger ones being provided with houses and all accessories. The sluices are left open as long as possible so as to permit the interior waters to flow to the river; but, when the flood rises, the master sluices, and, as the drainage accumulates in the main drain, the smaller sluices are also shut so as to isolate each area when the water gathers slowly. When the floods fall outside the gates are all opened again. The improvements it is found most advantageous to make in the drains are to strighten and shorten the natural channels by cuts; and to keep them always free from weeds, silt deposits and other obstructions. The main drain is always conducted to the lowest practicable outfall by carrying it parallel to the river till it reaches the lowest point of the ground drained.

Drainage practice in Lombardy.

29. In his Guide to River Hydrology &c. (1) Lombardini repeats these principles, and mentions some examples of drainage. Generally the above rules were followed; but in the Cremona territory between the Po and the Oglio there were noticeable peculiarities. About the year 1300 a cut was made which discharged into the Oglio near Calontone with a free out-fall. Its lower course was embanked. As irrigation extended this cut was found insufficient. In the XVIth century a new cut was made with a double slope leading one way into the Po with a free outfall, 9 kilometres below Cremona; the other, also with a free out-fall, was carried to the Oglio below Cremona. A much lower out-fall was thus secured, and a more efficient discharge was obtained. As the value of the land increased it was found expedient to add a sluice to the out-fall below Cremona, the additional ground thus reclaimed being sufficient to pay for the expense. The sluice however was not a success and resulted in injury to the lower lands. The whole of the hill waters was carried across the Cremonese plain by elevated canals which permitted all the excess water to flow over their banks into the subjacent drains.

The Cremonese Plains.

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(1).—Lombardini Sigr. Elia, Notize Su la Lombardia, 1844, Cap V. Stato idrografiico artificiale, p 156.

(1).—Lombardini Sigr. Elia. Guida allo Studio dell' Idrologia Fluviale &c., 1870 p. 103 et seq.

30. The drainage of the Pontine marshes has been often attempted. These consist of an old lagune of the Mediterranean, filled by river deposits. Taking the Appian Way as an axis, the rivers to the right are the Scaravazza, the Amazono and the Uffente; with the torrents Sermoneta and Teppia. To the left is the Cisterna, with a series of rivulets. The drainage area consists of 130,261 hectares (321,800 acres) of mountain land; while the plain to be reclaimed is 30,329 hactares (75,000 acres). Previous to the year 1777 attempts were made to carry the hill waters direct to the sea by separate channels. On the non-success of these a single channel, the Rio Martino, was opened to take the hill waters; but it also failed owing to the depth required for the cutting in the sand. In 1777, Pius the VIth undertook the work on a large scale through the Engineer Gaetano Rapini. He deviated from the rule of separating the hill waters from those of the plain; and cut a great central canal beside the Appian Way, to receive not only the drainage water from the plain, but all the hill waters to the right and to the left of the Way. The whole of the torrents were thus mixed with the plain land drainage. This plan totally failed at once; and the hill waters were again diverted by new lines passing round the plain to the sea. In 1787 a great flood ruined part of the works, and threw the torrents, particularly the Teppia, out of their channels, and these were thus allowed to carry their silt to the plain. The works estimated by Rapini at £22,000 in 1778, cost by 1792 over £300,000. Subsequently several engineers, amongst others the celebrated Baron deProny reported on the reclamation and proposed new plans. Some recommended that the warping of the plain by allowing the torrents to carry their silt into it to fill the low places should be systematically proceeded with as has been done in Tuscany. Prony recommended that instead of this, the large central drain of Rapini should be re-opened to serve for drainage. He allowed the necessity of carrying the hill waters by a separate channel and proposed that they should be gathered in the Rio Sisto, which should serve as a surrounding and gathering channel to conduct them to near the mouth of the main drain at Portatore. It is not known how far his proposals were carried out at the time; but the eminent Engineer Brighenti pointed out in 1847 that the discharge of the torrent waters into the slow flowing drain even at a few miles from its mouth was against sound principles and he recommended that the conducting channel should be carried close to the sea. Lombardini gives several other examples; amongst them those of the works in Holland; where from want of slope the water cannot flow away and has to be raised by machinery in order to run into the sea.

The Pontine marshes.

31. The Fens on the east coast of England offer important examples. The work of reclaiming these is one of the largest on record. Interesting accounts of the operations are given in Smiles' Lives of the Engineers (1) and in a paper read at the Institution of Civil Engineers by Mr. Grantham on Arterial drainage (2). The fen district is 130 miles long by 30 wide at its broadest part. About 800,000 acres of excellent land have been reclaimed. Formerly the whole area was submerged by inland waters from the higher region, by its own rainfall and by tidal waters from the sea. In some parts it is nearly on a dead flat below mean sea level. A very brief notice of the more important works, with a view of elucidating the principles by which success was obtained, is all that will be now given.

The English Fens.

32. The earliest attempt at the systematic reclamation of the Fens was made from the designs and under the direction of the great Dutch Engineer Vermuyden. The drainage waters from the Fens found their way to the sea by various irregular natural channels which meandered over the whole of the low area, and which, besides retaining the land waters, unduly permitted that from the sea to enter and check the outflow of the siltladen currents from the higher lands. The silt was thus

Vermuyden's works on the Fens.

(1).—Smiles Samuel. Lives of the Engineer, Vermuyden Rennie.

(2).—Grantham Richard Boxall. On artificial drainage and out-falls, 1859-60.

deposited irregularly and closed both drainage and navigation channels. Vermuyden introduced straight deep cuts to convey the inland water direct to the sea. An error was made in the execution of this work, as the cuts were first made in the interior lands, and, the rivers and drains being embanked, the water was thus conveyed rapidly to the lower lands, and as no fresh channels had been opened there, these were overwhelmed by the accession of the drainage from above. Smiles says :—"Vermuyden adopted the error of the Dutch system of drainage, in a district where the circumstances differed in many material respects from those which prevailed in Holland. In Zeeland, for instance, the few rivers passing through it were easily banked up and carried out to sea; whilst the low lands were kept clear of surplus water by pumps driven by windmills. There the main object of the Engineer was to hold back the river and the ocean; whereas in the Great Level the problem to be solved was how to provide a ready out-fall to the sea for the vast body of fresh water falling upon as well as flowing through the Fens themselves. This essential point was overlooked by the early drainers; and it has thus happened that the chief work of modern engineers has been to rectify the errors of Vermuyden and his followers, more especially by providing efficient outlets for the discharge of the Fens waters, deepening and straightening the river, and compressing the streams in their course through the level, so as to produce a more powerful current and scour, down to their point of outfall into the sea." The enumeration of the various cuts made by Vermuyden would be tedious. One was 120 feet wide and 10 feet deep, with sluices at both ends. Sluices were fixed at the mouths of the rivers to permit the outflow of the water, and prevent the influx of the tide. The older drains were deepened and the whole of the rivers except the Nene were straightened and deepened; and the greater part of the area rendered available for cultivation.

Errors in the earlier system of drainage.

33. This cultivation was, however, somewhat precarious, as the floods from the higher levels continually damaged the crops; and several Engineers have been called in to bring about a better condition of things. The Denver sluice, built by Vermuyden at the mouth of the Bedford river, where it joins the Ouse, was carried away in 1713. It was expected that the free out-flow would thus deepen the channel of the Ouse, which is the principal artery of the south level. Instead of this a deposit of silt occurred. The sluice was rebuilt in 1750, but still silt accumulated both in the Ouse and in the harbour of Lynn. The Eau Brink cut was designed to shorten the channel of this river by four miles out of seven. It was opened in 1821, and its effects fully justified the anticipations formed. It lowered the low water 6 or 7 feet at the upper end; thus permitting the sill of the sluice to be lowered. The Ouse was scoured out and deepened, and the tide entered the Bedford river. The cost of the work, which vastly exceeded the estimates, was £600,000. The river Nene, which formed the main drainage for the north level, continued in an unsatisfactory state. Kinderley in 1721 proposed a new cut to improve the out-fall. In 1770 his recommendation was partially followed and some improvement resulted; but only sufficient to prove that it would have been better to have carried out Kinderley's plans in full, and to have completed the work to the full size required at once. For many years inspections and reports were made on it; and Mr. Rennie finally devised a complete scheme of improvements. This was not put in hand till 1827. The principal work was a new cut in continuation of Kinderleys. Its size at the upper end was 200 feet wide at top, 135 feet at bottom, and 24 feet deep. At the lower end it was 270 feet wide at top, 160 feet wide at bottom, and 24 feet deep. Its cost was £200,000. Other internal drains and sluices were executed in connection with this at a cost of £100,000. The works were opened in 1834, and their efficacy was found to surpass the most sanguine expectations. The middle level remained to be dealt with. Its principal artery was the old river Nene, a very circuitous watercourse. Up to 1795 the whole of this level was in a most hopeless condition,

Further reclamation works for the Fens.

the river and drains having been choked with weeds and silt. In 1808 Mr. Rennie designed the above mentioned Eau Brink Cut, and in addition proposed to surround the district with catch water drains so as to entirely separate the hill waters from those of the plains. A third remedy he proposed was the straightening and shortening of the interior drains. The estimated cost of all these works was £1,000,000. The projects were not carried out as devised. His son, Sir John Rennie, and other engineers were afterwards consulted and several other projects were devised; but it was left to Mr. Walker to finally design and carry out the actual drainage works. He proposed not only to separate the high land drainage from that of the low land by catch water drains; but to further separate the drainage system from that of the navigable canals. He made several straight cuts for the main drainage, and deepened the old rivers and drains for some 110 miles from 4 to 7 feet, making their bottom widths from 12 to 30 feet. These works cost over £400,000; and further improvements have since been carried out by Mr. Hawkshaw.

The general principles of reclamation.

34. The general principles embodied in these works are similar to those found successful in Italy; and, indeed, in all similar cases. The first principle is to exclude as far as possible all exterior water from the area to be drained. The second is to carry the drainage from the higher ground by separate channels from that of the lower. The third, to improve the interior drainage channels by straight cuts, and by giving them sufficient capacity to ensure removing the low land drainage as fast as it is gathered. Questions as to giving free out-falls or sluice gates, and arrangements of main and secondary drains are matters of detail to be determined by the conditions of each case; but the above three principles are common to all such works, and cannot be deviated from without detrimental results. It appears also that they must be attended to in the order of time in the same sequence as above given. The reclamation works of the Myanoung plain have hitherto consisted exclusively of the embankment protecting it from the irruption of the Irrawaddy floods; and different proposals for continuing this work so as to secure the lowest expedient out-fall have been above considered. It remains to discuss the probable effect attainable by projects for regulating the hill torrents and the interior drainage channels.

Natural facilities offered for the reclamation of the Myanoung Plain.

35. It would be difficult to conceive an arrangement of hill and plain land offering greater facility for a thorough and scientific relamation of the lower plain, or the greater part of it, than is presented in the problem under consideration. The plain extends over 40 miles from north to south, and lies at the base of the Aracan Yoma between it and the Irrawaddy. On studying the configuration of the Yoma eastern slopes on the same length of 40 miles it is seen that these slopes are mostly occupied by the basins of three torrent streams, the Patashin, the Mamya and the Kanyeng or Okpho choungs. Dividing ranges separate the basins, and projecting spurs from these ranges close in on the channels of the streams where they issue from the hills and cause them to deliver the whole of the drainage from the hills at three fixed points. That of the Patashin is delivered to the north of the plain, and though the basin of this torrent stretches far south on the flank of the plain none of the water can now reach it. The Mamya basin occupies 105 square miles of the hill slopes directly opposite the centre of the plain, and it issues from the hills almost opposite the 32nd mile of the embankment. It turns north and empties itself into the Too Eng; and in the rains floods the country to the east and south. The Okpho choung whose basin runs east and west parallel to that of the Mamya has an area of 215 square miles. Its channel emerges from the hilly ground at a point about 6 miles south of the Mamya; though high land protudes between the two streams a short distance further east. All three basins are of surprising regularity in form both in their general outlines and sub-divisions. The Aracan Yomas here range from 3000 to 5000 feet in height, and consist of earlier tertiary clayey and sandstone schists

and shales, amongst which are found coal measures in a very dislocated state. The strata are considerably harder than those of the Pegu Yoma; but though they do not yield so readily to the disintegrating action of the rain-fall as the latter, a considerable amount of clayey silt is brought down by the streams. These, however, are not incommoded by the deposits, and flow in well defined channels through the plains. They evidently retain a considerable excavating power; and, so far as appears, are susceptible of being regulated with comparative ease.

Characteristics of the torrent basins of the eastern slopes of the Arakan Yoma.

36. The Okpho choung presents few marked features in its hill basin; or, more correctly, little is known of it; as, in common with the greater part of the southern Arakan Yomas, it is almost uninhabited. Beyond being worked by native contractors for a few teak trees found there it is rarely visited. Europeans almost never penetrate far into it; and it has most likely never been traversed by officers except when it was being surveyed. That this is the normal state of the Arakan torrent basins and slopes may be inferred from the fact that on the high road across the hills from Prome to Tounghoop on the sea side there is hardly to be found a trace of a habitation for over 90 miles. Yet this road is constantly traversed by travellers and cattle. Native huntsmen, mostly of the Kyen tribe, occasionally penetrate into the hill recesses; but their houses are invariably at the base of the hills either in Pegu or in Arakan. The writer has had considerable experienee on the Tounghoop road referred to, and from what he has learned regarding the more southern torrents will not be far wrong in assuming these to resemble the ones on the more northern line opposite Prome. On the Arakan side of the Tounghoop road the rain-fall is so excessive that notwithstanding the comparative hardness of the rock there is a considerable wear of the surface and disintegration of the ground. Occasionally a slice of a hill slides down, taking a piece of the road with it; but this is rare, and on the whole the road which was made over 20 years ago has stood fairly with some considerable repairs. On the Pegu side where the rain-fall is so much smaller, possibly not exceeding 100 inches yearly, the wear and tear of the ground surface is much less. In the more exposed positions where the road had originally been cut in hard shaley rock the road surface continued in excellent condition with clear sharp cut edges for over ten years; in other parts, where it had been carried in the softer ground, which sustained trees, bamboos &c., there is a continual wear by the weather and the rain-fall, which gradually removes the lower earth to precipitate it ultimately in the bed of deposit low down in the Irrawaddy Delta. But even in the heaviest rain storms the streams are not excessively overcharged with silt, and the degradation of the Arakan Yomas proceeds but slowly.

The Okpho Choung.

37. As a first result of this the Okpho creek retains a clear well defined section through the greater part of its course till it reaches the Sinpong. It has during the unrecorded years of its flow through the plain gradually raised the country in its neighbourhood as the line of levels run from Noukmee across the line of its course show. But the elevation is comparitively slight, and appears to have been caused by the continual spill from the stream at flood times sweeping slowly over the plain and leaving its accretion of fine clayey silt. At present the stream shows no signs of deterioration until it nears the town of Okpho low down in the plain. From enquiries made on the spot it seems to only rarely rise out of its channel in the upper part of its course in the plain; and it has no off-shoot whatever until almost at Okpho, where a stream called the Wutta opens out on its left bank and finds its way to the Sinpong. This was, formerly, say 20 years ago, only a small stream. It is now 140 feet wide, almost as large as the present stream, which ranges from 150 to 200 feet above Okpho. From this point to where it enters the Sinpong Choung, the Okpho stream rapidly deteriorates. In flood the current is so backed up by the Irrawaddy water, that it has had to rise out of the channel and spread over the

country. The excavating power of the water is thus dispersed and lost, and the channel shows signs of silting up; but only partially, as there is enough water left in mean flood when the Irrawaddy inundation is low to re-excavate and clear out, although insufficiently, the channel of the stream.

Deterioration of the lower trunk of the Okpho Choung.

38. A series of cross sections of its channel is given in Figure 7 from its first entry into the plain at Laygyee-gwin to near where it enters the Sinpong. The positions of these sections are marked in Figure 2; which gives on a larger scale the plan of the lower courses of both the Mamya and the Okpho. The diminishing areas of these cross sections prove that the Okpho undergoes the usual deterioration of hill streams, which on their progress through the plains are allowed to spill part of their discharge over their banks. So long as there is a sufficient fall in the plain land to permit the water to flow freely and re-excavate the silt deposited, the easiest and most obvious remedy is to embank both sides of the stream and cause the discharge to be retained wholly within the channel, which is thus kept in a sound and healthy state. The remedy appears paradoxical. The channel is, to all appearance, too small for the discharge, a portion of which escapes.

Paradoxical remedy for the deterioration.

The remedy proposed is to shut in to this already too small channel the additional burden of the escaping water; thus, at first sight, intensifying the evil. But this is in appearance only. Universal experience on torrents and rivers proves that this is the only possible means of ensuring the channel being kept with a clear section and a regular shape favourable to the easy flow of the water; and it is only the extending the principle derived from this experience one step further which has so often prompted the joining together of two or more separately flowing streams in the hope that they would mutually aid each others flow in the common channel. An application of this principle will be made in the present instance in proposing to join the Mamya to the Okpho Choung.

Different outlets for the Okpho Choung.

The abandoned one at Songong.

39. So far as the Okpho Choung itself is concerned it will be necessary, if all the Projects I to IV are carried out in their entirety, to carry the stream in an embanked channel down to the Sinpong out-fall. It would perhaps be found sufficient to give it a separate channel only so far as Kayenzeik by a tolerably straight cut from the village of Mayzalee. This would have the advantage of following an old abandoned channel of the stream which seems to have flowed in an almost straight line in the direction of Songong. It is traceable by a series of small lakes and lagunes and low uncultivable land. The present channel of the stream running towards Thambyading is of more recent origin; and is perhaps ascribable to the partial lifting of the stream out of its bed through the continually increasing afflux of the Irrawaddy waters with the progress westwards of the Thambyading bend; and to this also is most likely due the formation and development of the Wutta Choung within the last 20 or 30 years, which just now promises to absorb and divert the whole Okpho Choung to a new and shorter course to the Sinpong. However this may be, there is unmistakeable evidence of a retrogression of the debouchment of the Okpho Choung northwards simultaneously with the progress westwards of the point of that bend and the consequent elevation inland of the flood height. It would be wrong, however, to infer from this that now, with the retransfer of the Irrawaddy channel eastwards, and with the extension of the Myanoung embankment southwards, whether to Thambyading or to Songong and the lowering of the flood out-fall height, the Okpho Choung will find its way back of itself to its old course to Songong. It will be necessary to compel it back and to entirely exclude it from entering the plain land drains at any point above Kayenzeik if the complete scheme is carried out; but there is little chance of its doing this of itself. It has entirely changed its course from a point about 2 miles above Okpho, and

gradually formed an elbow eastwards towards the Wutta entrance, and these changes are, to all appearance, permanent. It will be a somewhat heavy work to re-divert the course of the stream so as to make it flow in its old line towards Songong; but it is one which must form part of the whole scheme to be carried out in concert with Projects III and IV for embanking the Thambyading and diverting the Sinpong Choung to Songong.

The Okpho Choung diversion, Project No. V.

40. Probably the undertaking will be much facilitated by taking advantage of the depressions existing in the old channel line from Mazaley, and past the villages of Kyoung-gon and Magyeegon. The exact cost of this cannot be now given; but assuming it to require an excavation 150 feet wide at top on an average, 30 at bottom, and 30 feet deep, it will for 2 miles in length at 1½ lacs of rupees (£15,000) per mile cost 300,000 Rs. (£30,000). In connection with this, the Okpho Choung must be embanked on both sides from its exit from the hills to Mayzalee the head of the proposed cut. All creeks, including the Wutta, issuing from it will be closed; and, as may be found necessary, a system of regulating works to control the current will have to be maintained for a few years. The diversion and regulation of the Okpho Choung will be numbered Project V.

The Okpho Embankment, older work.

41. The right bank of the Okpho Choung has already been partially embanked as far as Okpho by the agriculturalists who benefit by the protection afforded. The work is well laid out; but is too light to withstand the pressure during high floods, and has failed on every occasion when a higher flood than usual came against it. It has not been repaired properly since 1877. The upper portion of this extending from Okpho to near the hills has been made as a road with open culverts permitting spill water to pass through. The work is very creditable to the native official who laid it out and executed it; and, except that it is rather retired from the edge of the Choung and follows a somewhat straight course, it would serve as the line for the new embankment. A line of levels has been taken along the road and old embankment, and has been made to approach the creek in the most suitable places. The levels are given in Figure 11; and the required work is estimated for in detail in the Appendix. It is recommended that this work be put in hand as soon as possible, as, independently of its forming a part of the general scheme of reclamation, it has local claims of its own in the protection it can afford to the existing interests in the neighbourhood. The cost of the work is 35,900 Rs. for 10½ miles of the light embankments required, which is estimated at a height of 3 feet above the highest known flood marks.

New work proposed, Project No. VI Section I.

Second embankment for left bank of the Okpho Choung, Project No. VI Section 2.

42. This work will find place in the general scheme as Project No. VI. Under the same head but as a second section of the Project will be numbered the embanking of the left bank of the Okpho Choung. There is at present no urgent reason for taking this work in hand; but in any general and complete working out of the reclamation of the Myanoung plain it must enter. The work including the damming of the Wutta Choung and any other minor openings, may be roughly estimated at the same cost as the embankment on the right bank or 35,900 Rs. The proposals hitherto considered contemplate the alternative steps of carrying the out-fall for the drainage down the Thambyading river to Songong or Kayenzeik, or of leaving it until the Irrawaddy and the Nawoon entrances have assumed a settled régime, at Thambyading. In either of the former cases it would be necessary to complete in the most thorough manner the diversions of the Sinpong and of the Okpho Choungs to the new out-fall; and to also construct all the necessary embankment works. If the Thambyading out-fall is retained until the whole of the rivers and the country have assumed a settled con-

dition in this neighbourhood and the extent of the benefit resulting from the reclamation works put in hand is measured, neither the Singong nor Okpho diversions, nor the entire embankment of the left side of the latter need be undertaken. The bed of deposit of the Okpho Choung will practically commence at the Wutta entrance, and though below this the different channels will conduct the discharge to the Sinpong, there will continue to be a large spill over the banks with some deposit of silt in the country. But all this part of the plain must be expected to remain inundated during floods, as it stands below the level of the Thambyading out-fall, and if we consider the first stage of the reclamation of the Myanoung plain to have been achieved with the existing embankment to Loodauzoo, the second stage will consist of the extension of that embankment to Thambyading and the Noukmee Cut (Projects I and II) with the protection of the right side of the Okpho Choung (Project VI), and a most important work now to be considered; while the final stage, which is not to be commenced until all the other projects and changes have been successfully carried out will consist of the transference of the out-fall to Songong (Projects III and IV), and of the Okpho Choung diversion (Project V); with its complete embankment and regulation. The necessary drainage works for removing the rain-fall from the plain are implied as included in each stage of the reclamation.

Division of the reclamation works into stages or schemes.

43. When the Okpho Choung has been suitably embanked as far as the Wutta and to the town of Okpho, the Mamya Choung must be taken in hand. It is, in fact, the most important of all the undertakings in connection with the reclamation of the Myanoung plain; and though it cannot be the first to be executed with advantage, Projects I, II and VI prepare the way for it, and are only efficacious when this shall have been completed. It enters the general scheme as Project No. VII. As already pointed out the stream enters the plain from the Arakan hills about opposite the 32nd mile of the Myanoung embankment. It turns to the north, and, after flowing a few miles in a well defined channel, it loses itself in the Too Lake, the overflow from which inundates all the lower country from Kanoung southwards. The principles laid down for dealing with hill streams make it imperative that its channel shall be carried through the Myanoung plain without joining in any part with the drains of the lower plain. Three alternatives are open for disposing of it. 1st:—It may be carried direct to the Irrawaddy by the shortest available course across the line of the drains. 2nd:—It may be conducted through the lower plain by a natural or artificial channel parallel to the drains of the plain, and debouch at the common out-fall. 3rd:—It may be diverted by a new cut to join the Okpho choung and its discharge be carried by the channel of the latter in addition to its own.

The Mamya Diversion Project No. VII.

Alternative diversions considered.

44. A series of cross sections taken on the Mamya choung on its present course from where it leaves the hills to near its entry into the Too Eng is given in Fig 6. The highest section, that nearest to the hills, shows it as 80 feet wide and about 23 feet deep from the high flood mark to the bed. It retains much the same size for a few miles where the fall of the ground is rapid; but when it gets into the flatter country it assumes a broader and shallower section. Some miles below the first section shown it is 100 feet wide and 15 feet deep, while where the Shwe-gyeen line of levels crosses it, it is 330 feet wide and has become a shallow channel almost forming part of the Too lake. Whichever line the Mamya may be diverted by it is evident that a channel of similar dimensions to those first mentioned must be given to it; or say 100 feet surface width and 15 to 20 feet from its surface to its bed in the plain level land. If it were found necessary to take the Mamya direct to the Irrawaddy the shortest route would clearly be

Present size of the stream.

the best; and it could not do better than debouch immediately opposite its gully in the hills near the 32nd mile. There are certain determining conditions which would render this plan a most arduous one. The banks of the canal and the surface of the water in flood would require to be everywhere above the level of the Irrawaddy high flood level, both in order to facilitate the discharge, and to keep the flood from entering the plain. The canal would thus be carried mostly in embankment at a level of 12 or 15 feet above the general surface of the intervening plain. A canal of at least 10 miles in length would be necessary. As it directly traverses the natural lines of drainage of the plain the bed of the canal must be sufficiently high to permit the several existing channels to carry their water freely below the embankment; and this would limit the depth and increase the breadth of the canal. Its great elevation above the country and the great mass of water carried by it would render a breach of its sides most disastrous. In a word it would be a most expensive and risky project not be resorted to except under extreme urgency.

Project of a direct diversion to the Irrawaddy.

Difficulties attendant on it.

45. No such urgency exists in the present case. Either of the remaining alternations is preferable though each brings with it its own difficulties. The second alternative is to divert the Mamya immediately after it leaves the hills and by a direct cut running slightly south of east turn it into one of the natural drainage channels of the country flowing southwards. There is a small lake about 3 miles due south of Too-Eng; and from this the Sinpong Choung appears to take its rise, though the numerous lakes and old channels in this part render the matter doubtful. A cut from the Mamya to this lake would be two miles in length. A further cut of about half a mile would be required from the south of the lake to the Sinpong in order to open the communication thoroughly. The Sinpong thus offers itself as the only natural channel available for receiving the diverted Mamya. At present they have no connection whatever directly, as the Mamya water passes by a devious route through the Noukmee, which is in places connected by cross streams to the Sinpong. In order that this diversion of the Mamya should be really of service in reclaiming the country from inundation, it will be necassary to carry out the rule of rigorously severing all connection between the Sinpong and the other drainage channels of the plain country. It is at present the principal drain for the lower half of the Myanoung Plain; and all the previous projects for drainage include the Sinpong as the principal feature of the scheme. The present project requires that at any rate as far south as the Noukmee cut, it be completely excluded from all connection with them. Whether it would not deteriorate both its own channel and that of the drains at and below the Noukmee cut, if the Mamya were turned into it is doubtful, but seems most probable. In any case all the present openings from the Sinpong would be stopped, and it itself embanked throughout. The small lake might serve to receive the silt of the Mamya and allow the water to flow clear away, but it also must be embanked. In all two and a half to three miles of heavy cutting are required for this work with 20 to 30 miles of double embankment through extremely low country, and the loss of the service of the principal natural drain for removing the rainfall of this plain land; this, in all, probability necessitating the provision of another artificial drain 20 miles in length in its place. Any project which would avoid these difficulties as well as those of the Irrawaddy direct cut, has much to recommend it to consideration.

Project for diverting the Mamya into the Sinpong.

Probable evil effects.

46. Father Bringaud, a devoted French missionary, who has lived for the last 16 years on the banks of the Okpho Choung at Zoundan has proposed another scheme, which Mr. Hallett, Executive Engineer of the Embankments in 1873-75, gave much attention to. A small creek leaves the Mamya Choung a mile or two after it issues from the hills, and runs due south skirting the high

Father Bringaud and Mr. Hallett's project.

land for 4 or 5 miles and then turns west into a broad shallow lake called the Dapay Eng which lies nestled between hills on three sides. On the east a small creek issues from the lake and joins the Sinpong some 8 or 10 miles south of the small lake referred to in the last paragraph. A complete survey was made of the Mamya and of these smaller creeks under Mr. Hallett's direction and a line of the levels run along this route. It appears that Father Bringaud and Mr. Hallett propose to divert the Mamya into this small channel by a dam across its course, and by an embankment on the east side of the channel as far as the Dapay Lake, which would have the effect of keeping the water in the space between the high land and the embankment as far as the Lake; and then allowing it to issue from this Lake to the Sinpong. An embankment on the northern side of the eastward flowing creek would serve to keep the water from flowing to the north. This project has not been worked out to any completeness, and no written record exists in this office about it, so that it is hardly fair to criticise it from the data available. But unless other elements than those now stated enter into it, no satisfaction can result from carrying out the proposal. Both the creeks referred to are insignificantly small compared with the Mamya. The one leading from the Dapay Eng eastwards is not more than 8 or 10 feet wide and 3 or 4 deep; and though it takes away the surplus water from the Lake it can do no more than that. An embankment of sufficient height and strength might keep the Mamya waters enclosed between the high land and itself, especially if aided by the canal from which the earth for the work should be dug. But it is a very necessary precaution to take to carry all ordinary discharges of such a stream as the Mamya in a clear well defined channel so that it shall be susceptible of regulation; and it should be as deep in the ground as practicable. There is then some security that, even if a breach occurs in the embankments, the country will not be devastated, and the stream will not make for itself a new course. No advantage could result from leaving it free to spread between the single embankment and the hills; and it is not seen why it should be turned into the Dapay Lake, and then be allowed to course freely over the country.

A development of this project advocated.

47. The project is, however, not valueless, as it suggests the best course to be pursued with the Mamya, though neither of its supporters have contemplated this. If, abandoning the idea of carrying the Mamya in the little creek, a line parallel with its course be chosen, and a channel of sufficient capacity be excavated and embanked to carry the hill torrent as far as the Dapay Eng, why not continue the line 4 miles further and turn the Mamya into the Okpho Choung at Thekaybin, where the latter stream suddenly turns from an easterly to a southern course. The writer considers that this is the very best plan for dealing with the Mamya, though it brings difficulties with it, and its adoption can only be decided upon after a clear enumeration both of the advantages offered and the difficulties to be overcome.

Difficulties met with in this project.

48. The first difficulty is on the score of expense. A survey and levels of the line best suited for the proposed diversion has been made and are given in Figures 2 and 9. A fully detailed estimate and specification for this work and its accessories is given in the Appendix . One important accessory is a light embankment on the north side of the Mamya to cut off the spill water from the eastern plains. This will be joined to the dam across the creek and to the embankment on the south of the stream forming the eastern boundary of the canal. The canal itself will be excavated of the dimensions shown in figure 10. It would have been desirable to have carried the line of canal so that the quantity of earth excavated from it would about balance the amount required for the two embankments. A trial line was first run perfectly straight from the point of exit on the Mamya to the point of entry on the Okpho Choung. It was found that this passed through such low ground that for about a mile the bottom of the canal would

The embankments for the diversion are of greater dimensions than the cut, and regulate the cost.

have been only 4 feet in the earth. This was rejected, and a second which has now been adopted was run to follow partially the old course of the small creek to near the Dapay Lake, and thence in a straight line to the Okpho Choung near the village of Thekaybin. The projecting hilly ground near the Lake prevented the line being taken further west; and it was found necessary to include some low ground where the cutting is less than 7 feet for over half a mile. The rest of the ground is more favorable. The bank of the Mamya stands at about 71 feet + M. S. L., and the Okpho is nearly at 59·00 feet at the end of the canal. The flood spill of the creeks is very light at these points, and rises rarely over each bank. The heights of the flood rise at either end determines the height of the embankments to hold the stream. As the double embankments will require more earth on the whole than the cutting can furnish, the quantities have been taken out from these, and naturally fix the cost of the work. A light tramway should be used to carry the excess earthwork from the cuttings at either end towards the low ground in the centre of the canal. Any excess required will be taken from borrow pits well removed (50 feet) from the outer side of the embankments.

Special precautions to be taken for the embankments from the 4th to the 6th mile.

49. For the first four miles, and for the last $1\frac{1}{4}$ miles the canal is carried well in the ground, having depths of from 12 to 20 feet, while the embankments are comparitively light. Here the ordinary cross section of embankment used on the works will suffice, that is, each will be 14 feet wide at top with slopes of $2\frac{1}{2}$ to 1 towards the water, 2 to 1 outside. But as some uncertainty may exist about the flood height, a freeboard of 5 feet is given instead of three feet. But for the centre $2\frac{1}{4}$ miles where the embankments range from 15 to 22 feet in height heavier works are provided. The same top width and free board are given; but slopes of 3 to 1 and 4 to 1 are substituted. And to ensure that there shall be no scour by the water a facing of bamboo fascines shall cover both of the inner faces up to high water mark from the 4th to the $6\frac{1}{4}$ miles. This work is undeniably heavy and costly, as the $2\frac{1}{4}$ miles alone cost Rs. 5,29,422. The total cost for the 8 miles is Rs. 9,26,613. An attempt has been made to immitate the natural arrangement of section and slope in the canal. The slope has been fixed at $2\frac{1}{2}$ feet per mile in the first four miles, and at one foot per mile for the next four. The canal is almost exactly 8 miles long (2 feet less). The canal enlarges in width from 20 feet at the entrance to 30 feet at the $\frac{1}{2}$ mile; and after running at this width to $3\frac{3}{4}$ miles, where it gradually enlarges to 40 feet at the 4th mile, at which it continues to the end, thus broadening out as the natural channel does. The side slopes are throughout 2 to 1 on each side. A syphon consisting of two iron pipes 3 feet diameter will be placed under the canal to carry off the drainage from the Dapay Eng.

The Mamya regulating Dam.

50. The embankment to prevent the spill from the Mamya escaping is to be only a light work, which will terminate on an isolated hillock to the north of the dam. Some spill water may escape to the west of this and will find its way to the Too Eng; but, on the whole, this will be rather an advantage than otherwise. It will prevent an undue strain being brought on the embankments parallel with the cut, as it will serve as a waste weir to allow any sudden rush of water from the hills to escape. The Too Eng itself will benefit. This is the largest lake in Burma; it is about $2\frac{1}{2}$ miles long and $1\frac{1}{2}$ miles broad in flood, and is prettily situated at the base of elevated cliff-like hills surmounted by areca and other palms. It would be a great pity on more grounds than one to let this delicious lake dry up. At some future time it might even be found advantageous to embank and extend it, so as to act as a storage reservoir for irrigation to the lower land. In the mean time, if possible, a certain amount of water might be admitted to it to keep its surface high and the water sweet. With this end in view it is designed to make the dam across the Mamya serve occasionally both as an escape weir for

Too Eng.

the new cut, and as a feeder to the Too Eng. Designs for this dam are given in figure 9 Plate XXI. The lower part of the dam will be fixed and will consist of substantial iron wood piles, teak beams and sheeting piles with loose stone work above and below. On the lower side of the dam strong iron wood struts will help to sustain any shock or presure from the water above. The top of the fixed dam will be laid three feet below the top of the bank of the creek, or 5 feet below the present highest flood line. The dam as mentioned above will be carried by ironwood posts, to be fixed 10 feet apart from centres longitudinally ; these are to be carried 15 feet above the top of the dam, and each set will afford mutual support by cross diagonals of teak encased by teak planking to allow the water to flow freely between. There will thus be a series of 10 doors about $8\frac{1}{2}$ feet wide for the water to pour freely through. It is proposed to carry a bridge 14 feet wide on the top of the posts, with the flooring 12 feet above the top of the dam. Two feet below the flooring waling pieces are to be fixed on the upper side of the bridge to carry vertical timbers $6'' \times 4''$ like those called Poirie's needles in France. When it is desired to turn the whole stream down the cut the needles will be fixed in their places, and the whole discharge of the Mamya can be diverted. When, for any reason, it is desired that part of the discharge shall reach the Too Eng the needles can be drawn. To lessen the action of the escaping water on the bed of the creek this will be lined with stones, and rows of short piles. Substantial abutments and wingwalls will protect the ends of the dam for some distance and receive the earthwork of the lower embankment, which should also act as a roadway.

The total cost of these several works proposed for the Mamya diversion amount to Rs. 9,70,565. The detailed estimates and specifications are given in the Appendix.

51. It is to be understood that any further attempt to reclaim the Myanoung Plain must include some scheme for this diversion, which is absolutely indispensable. No extension of the Myanoung Embankment can by itself relieve the plain unless the hill water from the Mamya is excluded from it. The Irrawaddy water inundates the lower part of the plain at present, and disguises the effects of the Mamya, which is the true source of the inundation in the upper or central part of the plain ; and when the Irrawaddy floods are excluded the nature and extent of the Mamya flood damage will be manifest. The carrying out of the two works should be simultaneous ; or the diversion should be put in hand immediately after the extension of the Myanoung Embankment to Thambyading. It will be better to spend no more money on these works, than to leave this diversion undone, or to do it in an unsatisfactory manner. It is then a question as to whether the land to be redeemed is worth the expense to be incurred ; and next whether the plan now proposed is one of the least expensive and at the same time the most likely to be thoroughly successful of the different possible plans for the diversion. Of the two alternative plans proposed, the first, that conducting the Mamya direct to the Irrawaddy, may be said to be impracticable at any reasonable cost. The second one proposing to divert it to the Sinpong and to retain this for the sole purpose of carrying the Mamya is practicable ; but the cost of isolating it by embankments, and making the necessary cuts and stoppages of creeks will be very heavy and the whole scheme may turn out only partially successful and unsatisfactory, entailing large additional expense. The plan of diverting the Mamya through the shallow channels by a dam and light embankment appears inexpensive ; but, in the writer's opinion, would be most unsatisfactory, and could not by any possibility be successful. He has only to place on record an unqualified condemnation of it as an engineering project. The cut to the Okpho Choung with its accessories promises to be the least expensive, and the only project which can be guaranteed to be satisfactory in its results, so far as conducting the Mamya discharge to the Okpho Chouug is concerned. But here a new order of difficulties arises which must be considered.

The Mamya diversion is essential to the reclamation of the Myanoung Plain.

52. At Thekaybin where the Mamya cut enters the Okpho Choung the latter has a cross section of 1993 square feet, with width 125 feet and depth 22·36 feet. Up to this point the creek has lost little from spill, though in the highest floods a portion of the water passes over the banks to the neighbouring low lands. From Thekaybin to near Kanoo the channel keeps a tolerably regular section; but here it has of late years made a set eastwards and forms an elbow containing a wide reach of alluvion. From this elbow the Wutta Choung takes its departure and makes a short cut to the Sinpong, entering it considerably below the proposed Noukmee cut; but above where the Okpho Choung enters. The channel from where the Okpho Choung leaves the hills to Thekaybin is 8 miles long; and from this place to the Wutta it is also about 8 miles in length. An improved line for the Wutta would make its length to the Sinpong less than 2 miles and would bring it nearly within half a mile of the place where the older Okpho Choung debouches. The total length of channel the Mamya discharge would have to traverse on its new course after joining the Okpho Choung, would thus be in all about 10 miles.

The course of the united Mamya and Okpho stream.

53. It has already been pointed out that the present channel of the Okpho Choung in this part is somewhat small for the complete discharge delivered by its basin of reception at the exit gully from the hills; and that a portion continues to be lost in the downward passage, lessening the burden at successive cross sections. And the remedy proposed for the evil is, to shut entirely into the channel all the spill now lost, and compel it to excavate for itself a larger cross section. This we are fully justified by well grounded experience in expecting it to do, when the two sides of its channels are embanked. And not only this, but by throwing the Mamya discharge also into this channel the same well-grounded expectation leads us to believe that, very speedily, the channel will become large enough to carry the united discharges. The Wutta Choung will probably be the principal channel in future for the Kanyeng Choung if the things are left to themselves; or if the process is aided artificially. The comparatives shortness of the Watta channel when contrasted with the older courses of the Okpho choung will much facilitate the enlargement required. From Thekaybin to the Thambyading river will be only 11 miles, and the fall of the ground surface is, in this space, nearly 14 feet. The greater discharge increases the energy employed in erosion; and by regulative works such as light bamboo groynes concentrating the action at the most suitable places a complete control may be held over the whole process. The objections so strenuously urged against attempting to control the Irrawaddy do not apply here. The stream is altogether within the grasp of the engineer; and, with suitable precautions, can be guided to almost any desired end. And though no estimate of the cost can be given beforehand, there is every reason to believe the work will be inexpensive. But to leave a liberal margin a sum of Rs. 20,000 may be put down yearly for 3 years after the completion of the cut as the cost of the work. It will be sufficient to guide the stream in the first place to the Wutta entrance and past the town of Okpho, and then leave the stream free to act for a time; interfering only with its lower course if it is seen that it can be done with much advantage. But, while the Thambyading out-fall remains open, all this part of the country will be liable to inundation in flood and further work may be fruitless.

Proposals for regulating the united Mamya Okpho streams.

54. It would be wrong not to mention that while in the majority of cases benefit has resulted from concentrating the waters of one or more streams in a single well shaped channel, there is on record a very able protest against it relating to a particular case. The celebrated Hydraulician, Father Lecchi, published an eleborate essay, which occupies 134 pages of closely printed quarto in the Bolonga collection of Italian authors, on the three torrent streams Tradate, Gardaluso and Bozzente, which had been united in one channel and which he recommended should be again separated

Objections to combining two or more torrent streams in a single channel.

Father Leechi's Essay.

From 1500 to 1758 the last two torrents were united, the Tradate for the greater part of the time being kept separate. The united two were continually giving trouble, and when, towards the close of that period, the Tradate was joined to the others the evil culminated with the great floods of 1756, when they all left their channels, inundating the country with water and overwhelming it with silt. The region was in a measure depopulated and converted to a swamp. Lecchi lays down some principles for dealing with such torrents. He says that as each torrent brings down a large quantity of silt it requires a channel of a proper shape and suitable capacity, together with a sufficient surface fall to maintain its channel open by erosion. The discharge is always varying from flood to low-water; the channel therefore should be shaped to permit erosion of the silt at all stages of the water; that is, it should be narrow at bottom and wider out towards the top. It should be comparatively deep and narrow, not shallow and wide. It must thus, together with the embankments on its banks, just provide for the highest flood discharge and no more. A difficulty arises where two torrents are turned into the one channel as the times of their flood discharge may vary widely, coming down from their basins simultaneously or separately, so that the channel must be large enough for both though it may have to carry only one. A channel too large for the discharge favors the deposit of silt. There is thus a liability for each stream when flowing separately to fill and damage the channel instead of eroding it. There can be no doubt that the views given are sound, and when torrents bring down immense quantities of silt from basins in widely differing situations, and are thus liable to have their flood discharges at different times, it is highly probable that they will mutually damage their common channel if united together. But in case of the Okpho and Mamya torrents we have in the first place the basins of reception lying side by side in exactly similar conditions in every respect. No storm that visits the one can altogether avoid the other, and all ordinary rain showers must be shed equally over both. Their times of discharge must then be simultaneous, a fact which at first sight seems to militate against the course proposed but which is in reality the greatest recommendation for it. In the second place neither torrent brings down much silt. The water is discoloured in floods, and there is earth brought down; but, as is evident from the fact that the Mamya has been occupied for an indefinite period of time in silting up the Too Eng without much result so far, the quantity is too small to be hurtful in any way. While allowing therefore all the weight which Padre Lecchi's able investigations are entitled to command, the conditions of the torrents now considered are such as to remove them from the range of the objections brought forward.

Specific conditions of the Okpho and Mamya torrents which act in favor of uniting them.

55. The writer is strongly convinced that nothing but good effects can result from combining the two torrents in a regulated channel from Thekaybin southwards; but as it is always expedient to consider the event of a failure even when most improbable, it may be pointed out that it would be comparatively easy to turn the Okpho Choung itself down a new channel passing to the west of Okpho. There is here a broad low piece of ground extending from the Okpho Choung where it leaves the hills to the Nawoon River. It is a swamp, and has small lakes in it like the La Ho. Proposals have been brought forward by natives to redeem this land which is now wholly unoccupied, but they are ill-considered and cannot be successful. It might benefit this land to give it a course of silting from the Okpho Choung such as has raised the site of the town of Okpho. The creek would cut its own way through the swamp if turned into it by a dam and an opening. But there is not the slightest chance of any such measure being required through the diversion of the Mamya.

56. The moveable upper dam for the Mamya will aid much in regulating the discharge through the Okpho Choung. The inundation of the Myanoung plain is caused less by the sudden floods of the Mamya than by the continuous inpour of its ordinary half or three quarter flood discharge. If

The moveable dam for the Mamya Choung.

all the water of these periods were diverted from the plain a large reservoir would be available in the Lake and in the lower grounds to receive the surplus of the high flood discharge without damage. And it is the half and three fourths floods discharge which would best help the excavation of the united channel, of the torrents as they would meet corresponding discharges from the Okpho Choung basin. It will be well therefore to permit a large flood escape by the dam and bank of the upper Mamya for the first few years until the régime of the lower Okpho is finally established. By that time questions will have arisen as to sources of water for irrigating purposes, the want of which is already felt behind Myanoung and Kanoung. The Patashin, the Mamya and the Okpho Choungs will all doubtless be called upon to furnish their share of this.

The works comprised in Scheme II must be completed before Scheme III is commenced.

57. The works now considered under the heads of Projects I, II, VI and VII, including the extension of the Myanoung Embankment to Thambyading, the Noukmee Cut, the Okpho Embankment, and the Mamya diversion, constitute the second stage of the reclamation of the Myanoung Plain. Not until all these measures have been finally achieved and their results carefully noted should the third stage be taken in hand. Probably by that time some more feasible projects than those considered will have been suggested. It might, for instance, be found cheaper and better to place a large sluice at the present mouth of the Sinpong, and embank round the lower edge of the plain, and dispense with the costly cuts necessary to transfer the free outfall to Kayenzeik or Sinpong. But no decision can well be come to on the advantages of a free outfall, or of a closed and sluiced outfall, until a long series of observations have been made not only over the country remaining inundated, but on the river variations in height at Thambyading near the Sinpong outflow. If it can be shown that the river surface remains at a level above that permitting the drainage of the country to flow outwards for so short a time that on an average of years the interior drainage shall not be able to accumlate inside with disastrous effects, a sluice would be the best measure, even though it will be expensive and require continual attendance. It is on the supposition that the drainage will accumulate disastrously, which seems the most probable event, that the Sinpong free outfall is recommended.

The present natural drainage of the plain is of great capacity and suited for much larger requirements than those of the reclaimed plain.

58. It remains to consider what measures should be taken to improve the interior drainage system when both the Irrawaddy water and the hill torrent water shall have been excluded or effectually controlled. A study of the larger scale map showing the principal water courses of the plain proves that this is already provided with a very efficient natural system of drains. And it is necessary to state that owing to the absolutely impracticable nature of the centre of the plain, which is covered with the very densest jungle barely open even for foot travellers in its greater extent, and swampy and impassible for nearly 9 months out of the 12, the area has been little surveyed, and only a few of the larger creeks and lakes near the lines of cart roads, are shown. In the parts the writer has visited there are creeks not put down in the map, and it must necessarily be the same all over this central area. The fact that the spill water from the Patashin and the Irrawaddy floods, with the discharge from the latter through numerous creeks found its way in addition to the Mamya torrent discharge by these drains continuously in this part, proves them to have already a large capacity. The greater part of this burden will henceforth be entirely cut off and diverted; and, it is anticipated, the remainder may easily be carried by these channels if only they be kept free from fishermen's dams, and be occasionally cleared from overgrowths of jungle.

59. As a matter of fact we have no detailed surveys of these creeks throughout their lengths, and it will be difficult and costly to make complete surveys owing to the wild nature of the country. It will be better to await the result of the protective operations, when all obstacles to the free flow of the drainage will develope themselves and each can be examined separately and the suitable remedies applied to it. No general scheme needs elaborating. The existing drains are sufficient generally, but improvements may be locally applied when the requirements are manifested. In the meantime an examination of the levels taken across country yields an indication of what the present means of drainage are, and gives valuable information as to the relative levels. The Kanoung line shows only two comparatively small streams following the lowest part of the country. The largest the Mugyoung Din lies some 8 feet below the lower land near to it and ultimately flows into the Noukmee Choung. It is possible that here some opening out of the creek might be useful; but the stagnation of the Mamya flood waters renders it difficult now to pronounce. Little or no hill water enters the plain above this point, and there is only an area of 80 to 100 square miles of plain land above the line. On the Shway-gheen section line there are several smaller drainage channels, and there is a creek the Taik Choung nearly 300 feet wide and 25 feet deep at centre; its bottom standing at 31·89 above MSL. Another creek the Taynee is still broader and deeper, being over 500 feet wide and 26 deep, its bed standing at 28·66 feet, + MSL. Both of these form the upper portions of the Noukmee, the latter having received the overflow from Too-Eng. The Sinpong has no existence on this line. It shows itself, however, on the Nyoungyo section line as a well defined creek between 300 and 400 feet broad, with a narrower deep channel at 32·50 feet, + MSL. It thus stands above the bed of the Noukmee on this line, which reads 22·58 feet, + MSL, and is 27 feet deep by over 300 feet wide. There are other depressions in the ground all capable of taking away large bodies of water. Near Noukmee, as the accurate levels and measurements before given show, both the Noukmee and the Sinpong are much reduced in size from the last sections; but both are near their out falls; and the water has a more rapid flow. The Sinpong is now the largest and its bed the deepest, and it has become the principal drain for the plain. Even here several parallel depressions in the ground will convey away the drainage; but until it is seen how the several drains act after the Noukmee Cut and the other works have been done, it is unadvisable to prepare measures for improving these drains, beyond clearing them of fishing and other obstructions.

Prevailing ignorance of the dense jungles and forest tracts of the Myanoung Plain.

60. To recapitulate briefly the conditions of the Myanoung Plain and the stages of its reclamation, these are: the Myanoung Plain is a shallow saucer like depression 40 miles long by an average of 13 wide lying between the elevated right bank of the Irrawaddy and the Arakan Hills. It formerly received water from the Patashin and Irrawaddy flood spill, and from side streams opening from the latter. It still receives the whole discharge of the Mamya torrent and part of that of the Okpho torrent, as well as its own rainfall of over 500 square miles. The water formerly lay over almost the whole of this area in very high floods, preventing safe cultivation. An embankment 44¼ miles long has been completed from the hills round the north and east side as far as Loodauzoo, constituting the first stage of its reclamation. The effect of this has been to effectually protect all the upper part of the depression and a portion of the side in the middle of its length. The centre of the plain from within ten miles of its upper end is still inundated, and the inundated area increases in width and extent proceeding southwards till in the lower end of the plain all is submerged in even ordinary floods. The inundation in the centre of the plain is partly due to the Mamya and Okpho torrents, partly to the Irrawaddy high flood water. It is proposed to reclaim the whole of the centre of the plain, and some part of the lower end of it by a series of works to be included in the second stage or scheme of the reclamation. Those

Recapitulation of the Schemes for reclamation of the Myanoung Plain.

works are :—to extend the Myanoung Embankment from 6 to 7 miles southwards, lowering the outfall level by about 3 feet; and connecting the Noukmee to the Shpong by a cut. To divert the Mamya and wholly exclude the pernicious hill waters from the area to be reclaimed, by embanking the torrent as far south as Okpho. The third stage, which is not to be commenced till the second one is satisfactorily worked out, will include the entire surrounding of the reclaimed area by embankments, and either of the alternative schemes of a free outfall at the lowest possible point near Songong, implying the diversion of the Songong drainage stream and of the channel of the combined Okpho and Mamya torrents to that point; or, of leaving these streams in the condition they are found in after the second stage is done with, and retaining the outfall at Thambyading, where it will be closed with a sluice to be worked by hand when the floods are up.

Personal observations on the Myanoung Plain.

61. It is not possible to give an accurate comparative statement of the cost of the works of these several stages with their results in reclaiming the land, but an approximation may be made to it. The total cost of the Myanoung Embankment up to the end of the financial year 1877-78 was Rs. 9,84,722. It protected 35,314 acres of land cultivated before the work was completed, and 22,291 additional acres have been brought under cultivation in consequence of its construction. In all, therefore, it protected in 1878, 57,605 acres; or making allowance for fallow land, and for land kept as common by the villagers for grazing &c. about 100 square miles. So far as personal observations, made in a desultory manner at different points of the bounds of the inundated area, serve to form an opinion, it appears that the cultivation presses hard on the area yearly inundated. The villagers declare that they would be only too ready to extend the area of cultivation if the land were made available for them; in some places they state that they could multiply it ten-fold. This is in the immediate neighbourhood of the swamp. The ground is of the most excellent quality, being virgin land, covered with a dense forest jungle. In many cases the cultivation is extended to the low land on the chance of a high flood not coming. In the older settled parts there is hardly an acre of land available, except to the west of Myanoung and Kanoung, where high and somewhat stony land extends in a mass and in isolated patches. This is sometimes utilized for fruit gardens &c. The 100 square miles of land recorded as protected may thus imply altogether nearly 150 square miles ultimately available behind the Myanoung Embankment, and receiving an immense accession of value from the existence of that work, but in the revenue account only the 57,600 acres or 100 square miles are admitted. In round numbers these 100 square miles have cost 10 lacs of rupees (Rs. 940,833) to protect them, or at the rate of 10,000 Rs. per mile or over 15 Rs. per acre. A land tax, averaging $1\frac{1}{2}$ rupees per acre, is levied on all this land; and as a return for the protection afforded, the whole of this is credited to the embankment works for the 22,291 acres of reclaimed land; while only 4 annas per acre, or $\frac{1}{4}$ rupee, is credited to the work for each acre of land formerly cultivated, but now protected. The total revenue for the year 1877-78 was thus 43,193 Rupees. The interest at $4\frac{1}{2}$ per cent on the capital was 42,862 Rupees. There is further an annual charge for maintenance which amounted in 1877-78 to 7951 Rupees, bringing the total charges against the work for the year to 50,813 Rupees, thus showing a loss for that year of 7,620 Rupees.

The work of reclamation already achieved.

62. Similar losses have been recorded against this work in previous years, which bring up the total deficit standing in the book account against the Myanoung Embankment (first stage of the reclamation works) to Rs. 3,86,794. It is to be remembered that this is only a book account, where the items denoting profit or loss have been arranged arbitrarily. All the indirect returns which were formerly admitted in favor of the embankment have been excluded, although it is certain that if the work did not exist no such returns

Book accounts of the Myanoung Embankment.

could have been credited to Government for that area of land. And the charge of four annas per acre for protection to the land previously cultivated seems insufficient when it is considered, as pointed out by the writer, whose words are quoted in the Revenue Report for 1877-78 "that in each of the flood years 1868, 1871, 1875 and 1877 the whole of the area behind the embankments would have been entirely submerged and the crops destroyed, but for the embankments; that is out of the ten flood seasons, 1868 to 1877, the embankments actually saved not only the area reclaimed by them, but also the greater portion of the area formerly cultivated, four times from destruction. In several of the other years also a large part of the area formerly cultivated would have had a precarious existence." The writer made this statement with a view to urge a higher rate than 4 annas per acre, which is only one sixth of the revenue, being allotted as a return where the protection given is in the ratio of 4-10ths. If this rate, which is a very small and reasonable one, were allowed, or 10 annas per acre on the protected land were shewn as a return for the cost of the works, the revenue for the year 1877-78 would stand thus :—Acreage reclaimed 23,726 acres at 1-8=34,365 Rs. Acreage formerly cultivated and now protected, 35,314 acres, at 10 annas, 22,071 Rs. The total revenue would thus be shewn as 56,436 Rs. for the year against an expenditure of 50,813 Rs. leaving a balance of 5,623 Rs. to go to wiping off the deficit shown against this work for former years. The whole affair is merely a book transaction, as the total revenue of 1-8 per acre is received in hard cash. By the present arbitrary and inequitable arrangement this important reclamation work is shewn as tending directly towards bankruptcy without a possibility of avoiding that result. It is improbable that much further extension of cultivation can take place until the second stage reclamation works are undertaken and these must stand on their own merit.

Desirability of increasing the rate allotted for protection of cultivation.

63. The estimated cost of the various projects included in the reclamation works of the second stage for the Myanoung Plain are :—

Estimated cost of the different Projects comprised in Scheme No. II.

Project.		
I.—Section I embankment 44th to 50th mile	...	Rs. 40,000
II.—Cut from Noukmee Choung to Sinpong Choung	...	„ 80,000
VI.—Section I embankment on right of Okpho Choung	...	„ 36,000
„ II „ left „	...	„ 36,000
VII.—Diversion of Mamya Choung with accessories	...	„ 10,00,000
Regulation of united channel of Mamya and Okpho Choungs for 3 years	...	„ 60,000
VIII.—Improvement of drainage Channels of Myanoung Plain	...	„ 60,000
	Total Rs..	13,12,000

This total may be estimated to include unforeseen further expenses, and it is possible that the amount may be much reduced; but as the work includes some uncertain elements it will be well to take a sufficiently broad margin to cover these uncertainties, and thus be on the safe side.

64. If as is intended and hoped, the present drains of the plain prove sufficient to remove the rainfall from its surface without stagnation or accumulation of the water by the execution of a few light improvements; and all the hill waters, or all that is pernicious of them be absolutely excluded from the upper and middle plain by the diversion and repelating works, we have only to consider in estimating the extent of land to be reclaimed, how far the Irrawaddy flood waters can extend within the area round the end of the embankment at Thambyading in such a flood as that of 1871. Figure 3 shows that almost the whole of the land on the Nyoungyo line, which starts at the 39th mile of the embankment, is well above the highest water level. A few of the lowest parts nearest to the great drainage creeks are below the Thambyading 1871 flood level (47 feet + M. S. L.) and the water could still flow southwards in these without injuring the country. On turning to *Plate V showing the heights of the flood*

Approximate estimate of the results to the country from carrying out Scheme No. II.

waves it is seen that both Shoaygheen and Nyoungyo gave imperfect records in the year 1871 owing to the gauges having been carried away. Comparing however the Myanoung and Henzada diagrams, we may suppose that Thambyading is a mean between the two, though more closely approaching the latter, and that these show that the crest of the wave was for only 20 days at a height above 3 feet from its highest point, and at Henzada it rose for 25 days above 2 feet below its highest. We may assume that it was intermediate between these times and heights at Thambyading, say within 2¼ feet from its highest point; for 23 days. This height is represented by the Nawoon flood line on the figure. In 12 of those 23 days the water would be flowing inward very slowly, and in 11 would be flowing out again to depart finally with the permanent fall of the high flood. In this time it could hardly reach the Nyoungyo line; but it would leave no hope of the country between Noukmee and Okpho escaping. Even in ordinary flood any rice cultivation in this neighbourhood would be precarious, though a difference of four feet in the river height from that of 1871 would probably leave this line available for cultivation. The line of absolute protection may thus be drawn with its crest to the south of the Nyoungyo line, and must be to the north of the Noukmee line, nearer the former than the latter. And it will curve round concavely to the south leaving protected land towards the Okpho Choung to the west, and near the embankment to the east. Practically by far the larger portion of the Myanoung Plain will be redeemed by the second stage operations. A line roughly drawn (Fig 2) shows the anticipated boundary of the land remaining damaged by an Irrawaddy 1871 flood, which when measured on the map gives about 400 square miles of the whole Myanoung Plain, containing over 500 square miles, protected and reclaimed. Of this from 100 to 150 are due to the works of the first stage as already shown, leaving 250 square miles rendered available for culture by the second stage works; or, deducting 50 square miles for lake and stream surface, for roads, &c., 200 square miles, all of which including grazing lands may be made subject to land tax. The present rate of 1-8 per acre will yield on this 1,92,000 Rs., a return of nearly 20 per cent upon the outlay.

Approximate statement of the financial results.

65. There is no possibility of doubt as to the fact of there being a comparitively large population already living on the edge of this inundated land, both in the interior villages and on the river line, who will take up portions for cultivation immediately it is rendered available. The average size of the holdings is from 6 to 10 acres per cultivator. It is probable that during the first two years at least 20,000 acres of new land will be taken up; and allowing three years free of tax to encourage the extension of cultivation, there will be in five years a return of 30,000 Rs. upon the works. From the rate of extension known to have taken place in other parts of the Henzada district, it is reasonable to expect that there will be a steady annual increase of the cultivated area of from 4,000 to 5,000 acres. The lower figure will give 6,000 Rs. yearly increase., The accounts of the return will then stand from the commencement of the works.

	Acres yielding revenue.	Rupees.
First five years,	0	0
Sixth year	20,000	30.000
7th „	24,000	36.000
8th „	28,000	42,000
9th „	32,000	48,000
10th „	36,000	54.000
11th „	40,000	60,000
12th „	44.000	66,000
13th „	48.000	72.000
14th „	52,000	78,000
15th „	56,000	84,000
16th „	60,000	90,000
17th „	64,000	96.000
18th „	68,000	1,02,000
19th „	72,000	1,08,000
20th „	76,000	1,14,000

These figures are, of course, inaccurate, and only serve to show the process by which works of this kind, can be expected to become remunerative. The Henzada embankment has, within ten years of its commencement on a large scale,

proved so profitable that even with the restriction to direct returns from land tax, and a four anna charge upon protected land, it has not only paid interest on its own cost and expense of maintenance but has cleared the accounts of the other older works shown as themselves unprofitable.

Final recommendation.

66. From the nature of the operations required on the Mamya diversion it will not be possible to carry this work out in a tentative manner and the whole work must be thoroughly completed and made safe before any water is admitted to the Canal. And both the Okpho right embankment and the Noukmee cut should be completed entirely and thoroughly at one operation. The remaining works may be delayed as long as found desirable. Great care has been taken to provide a large price and a sufficient margin in the estimates for the cost of all the works, as it is better to err on this side in the beginning than to mislead by hopes of exaggerated profits at little outlay. But at the same time the writer believes that the whole of the works will only cost three fourths of the amounts shown. He has purposely put the rate of earthwork both for the Noukmee and Mamya cuts at 1 rupee per 100 cubic feet, although he has done work quite as heavy at an average cost of $\frac{3}{4}$ths of a Rupee ; and could guarantee to do it in these cases. The unforeseen expenses also have been heavily estimated ; but, after careful consideration, no present data permit any such cause of expenditure to be foreseen. Sanction, however, should be accorded to the larger sums, while every endeavour should be made to reduce the cost. In the same manner the probable profits have been very much under-estimated. It is now no longer a matter of conjecture what returns these works must yield. The experience of the last 10 years shows conclusively that immediate returns on a large scale may be expected ; and deferred returns to a much larger extent than those shown. These expectations, however well grounded, had perhaps better not be put forward to recommend the works for sanction ; and only the most rigorous demands, and the least favorable anticipations should be made the basis upon which the works proposed should receive sanction. If possible, the whole of the money required should be provided for one season's operations, and timely notice, not later than August of the year, be given to make the requisite preparations ; when the whole can easily be completed before the next year's floods.

SECTION II.

Characteristics of the Nawoon River.

Reason for placing on record an account of the effects of the floods on the Nawoon.

67. The great floods of 1875, 1876, and 1877 upon the Nawoon river gave rise to results of the highest interest, not only on account of the damage threatened or inflicted on the embankments, but in the prominence they gave to the permanent changes induced on the régime of the river by the extension of those works. Several reports were sent in at the period of the occurrence of the floods, but these were more or less disconnected, and related principally to the local and temporary matters of interest, such as the breaches, the damage done, and the efforts of the authorities to avert or remedy disaster. It is the purpose of the present Part of this report to place on record a coherent account of the facts and features of more permanent interest; whose value will consist not less in being a guide to the results which may be expected from future works than in registering the past.

The variableness of the data to be recorded.

68. In analysing the effects and the causes of these floods some of the elements and factors are very changeable, while others appear permanent, and it would seem that the best plan of procedure would be to separate the two kinds; and, after examining the more fixed relations, to find how far these are changed by each of the varying conditions. While admitting that this would be satisfactory if a complete knowledge were possessed of the whole series of facts relating to the history of the river for a lengthened period, it is to be regretted that information of this kind is somewhat scarce and indecisive, and extends only over the time during which the works have been in progress, and reaches in each period little beyond the neighbourhood of the works. And from what has before been said, it is seen that, in some cases where we might expect fixity of condition, there has been, and is still in progress, change of the most extreme kind.

Variation in the sources of the Nawoon.

69. Thus the sources of the river to the north of Thapangyo, the principal measuring station of the Nawoon, have continually varied. Native testimony insists that the Irrawaddy formerly sent off a branch to the north of Myanoung, which flowed through the Myanoung Plain, carrying with it not only further accessions of spill from the lower part of the Irrawaddy Channel, but the discharges of part of the Patashin, and of the whole of the Mamya and Okpho torrents. When this arm ceased to flow, the true Nawoon branch, which opens about 8 miles north of Henzada, became the main feeder of the Nawoon. In the beginning of this century this branch commenced to close, and finally ceased to serve as a dry weather channel many years back; while subsequently it almost entirely became dammed up even for flood communication. The Patashin and the Mamya torrents then discharged into the Irrawaddy, and probably also the Okpho, though this seems doubtful, at least for its whole discharge. The greater part of the rainfall of the Myanoung plain, and the spill from the Irrawaddy into this, must then have gone into the Irrawaddy. Almost the entire supply to the north of Songong would thus have been cut off from the Nawoon river, but that the Thambyading, which was formerly a small prolongation of the Okpho Choung carrying part of its waters to the Irrawaddy, gradually enlarged, its course getting reversed, and it became a tributary of the Nawoon, of which it is now the principal source, opening from the Irrawaddy about 5 miles above the old Nawoon entrance.

70. The extension of the Myanoung embankment between 1862 and 1868 has tended to give more permanence and regularity to these sources; which will be determined finally or for a long period of time, when the reclamation works for the Myanoung Plain shall have been completed, and the changes still operating at the Thambyading bend have ceased. The spill from the Irrawaddy is now mostly excluded; and except that which flows through the Nawoon and Thambyading entrances, the water supply from the large river will ultimately be cut off. The drainage from the Mamya and Okpho torrent basins, and from the Myanoung Plain will be entirely turned into the Nawoon; and the river may be expected to take a settled régime, as its other contributing watersheds to the south of Thapangyo are little likely to alter in character or extent.

A tendency to permanence in these sources.

71. If there were any data on record of the earlier changes in the channel of the Nawoon due to the enormous alterations in the volume supplied from the upper sources of the river, they would be of the utmost value in estimating the effects of the different elements in causing the later changes. What was the effect of the Nawoon closing, and of the river losing the supply from the Myanoung Plain and the contiguous torrents? Unfortunately no information is available on these points; though it seems probable that there must have been a great lowering of the river surface in flood when the supply was greatly lessened. There must have been also a shrinking of the channel, probably with accessions of deposit near the banks. And in the period before the embankments were constructed on the Nawoon itself, while the Thambyading was enlarging, some alterations must have taken place in the flood height of the river surface and some enlargement have occurred in its channel throughout its course.

Paucity of evidence as to the earlier changes.

72. This process of enlargement of the Thambyading entrance continued through the period of the greatest extension of the Nawoon embankment works. These were commenced in 1869, when four miles were completed, which practically could have had no influence on the flood in 1871. The highest points reached by this flood were carefully marked as far south as Ngathaingyoung, and subsequently connected by accurate levellings by Mr. Richard, who afterwards extended them as far as the Taboo Choung or Taboo Wa (Wa=mouth). Below Ngathaingyoung the markings are not quite as accurate as above. They have since been further carried to the Daga-Wa. The embankments have been sanctioned as far as Taboo-Wa, and are proposed to be terminated at the Daga. The working season of each year generally lies between November and May. In that of 1871-72 the embankment was extended to the 25½th mile, in that of 1872-73 to the 40th, in the two seasons 1873-74 and 1874-75 to the 53rd mile; and in that of 1875-76 to the 70th mile in a continuous line, while about two miles more have been thrown up but not joined on to the rest. Taboo, the termination of the works at present sanctioned, is at the 79½th mile; and the line to Daga-wa reaches 99½ miles.

Changes on the trunk of the river and extension of the embankments.

73. The years of great rainfall and flood 1871,1875, 1876 and 1877 nearly coincided with the extension of the works, that of 1871 preceding them, while that of 1877 followed their latest extension. There are thus three sets of circumstances which severally or united could serve to produce extraordinary floods on the river channel; 1st. The changes in the magnitude of the upper sources of supply, and in the river itself; 2nd. The effect of the embankment works in shutting in the spill; and 3rd. The variation of the rainfall on the watershed of the river. Before examining, in so far as the data allows, the shares of these different causes in producing each flood, and in finally ascertaining the permanent effect on the river and on the works, it will be well to survey the broader results known regarding these floods. In table 33 are given

Principal data of the great floods upon the Nawoon; and probable causes of the floods.

the heights of the various floods above mean sea level at the principal stations on the river; as well as the differences between the later floods and that of 1871. The principal object of the enquiry is to find how far the embankment works are responsible for producing the remarkable differences shown.

Table 33.

Station.	Distance in Miles.		Flood heights above Mean Sea Level in feet.				Differences from 1871 flood in feet.		
	From Thambyadeing by river.	From Nawoon by embankment.	1871.	1875.	1876.	1877.	1875.	1876.	1877.
			Feet.				Feet.		
Thambyading ...	0	...	47·00	48·00 (?)	...	86·36 (?)	...	...	...
Nawoon	...	0	44·76	45·70	...	46·10	0·94	...	1·34
Myogwin	8	11½	41·44	43·20	41·25	44·26	1·76	0·19	2·82
Leymyetna	30¼	25½	32·16	33·91	33·26	35·41	1·75	1·10	3·25
Zimbyogong	42¾	35½	27·86	30·11	29·27	31·86	2·25	1·41	4·00
Ngathaingyoung ...	64½	47	22·29	24·29	24·79	26·62	2·00	2·50	4·33
Mageelaha	87	60	16·39	17·42	19·97	21·51	1·03	3·58	5·12
Zeebingwin	98	70½	12·96	13·36	14·40	14·98	0·46	1·44	2·02
Taboo-Wa	107½	79½	9·62	...	...	10·62 (?)	...	...	1·00 (?)
Shoaynyoungbinwa ...	116	86½	8·47	...	...	9·47 (?)	...	...	1·00 (?)
Daga-Wa	127	99½	7·86	...	...	8·56 (?)	...	...	0·70 (?)

At the same time the heights and differences on the Irrawaddy were at the following stations:—

Myanoung	...	...	70·15	70·91	67·70	71·87	0·76	−2·45	1·72
Henzada	...	...	42·48	43·48	41·30	43·78	1·00	−1·18	1·30

The general features of the different floods.

74. The differences shown in the last three columns give the characteristic results of the effects of the embankment works on the Nawoon line, taken in conjunction with the other causes operating. To ascertain how far these concurred in producing the particular effects it will be necessary to pass them in review in detail, but before doing this the significance of the figures given above may be noticed. The 1871 flood was, up to the time of its occurrence, the highest on record upon the Irrawaddy. The causes producing it, heavy rainfalls over the Irrawaddy Valley, extended to the Nawoon region; and, as far as is known, it was the highest flood ever seen on that river also. It rose over the alluvial banks on both sides of the river, and was generally parallel to them, a fact which may be accounted for by the spill flowing every where over the plains, on both sides, which were entirely inundated. As before observed, it was not in any way affected by the embankment works, which only extended then for four miles along the Nawoon. It is thus a representative high flood of the river in its state antecedent to the execution of the protective works. The flood of 1875 rose over that of 1871 nearly a foot at the entrance from the Irrawaddy. It would therefore be natural to expect the river surface to stand higher throughout its length, provided there were as great a rainfall on its watershed as in 1871. We find, in fact, that the excess gradually increased through 1¾ feet for 30 miles to 2½ feet at the 43rd mile; and again gradually diminished on going southward. There is some doubt about the figures at the lower two stations at the 87th and 98th miles, but there is no doubt that the

excess diminished much in these parts. The 1876 flood presents still more remarkable features. The embankment, which extended in 1875 to the 51st mile, and which stood the extraordinary strain upon it without failures, had, in 1876, reached the 70½ mile. Originally the work was constructed with a free-board or extra height of 3 feet above the 1871 flood level, excluding allowance for shrinkage. The 1875 high flood had proved the necessity of giving greater freeboard, and estimates were prepared and sanctioned with this end; but sufficient money was not available to carry the embankment to the full height desired. It was thus taken by the 1876 flood in a soft and unfinished state. This flood although 2½ feet lower at Myanoung and 1·18 feet at Henzada than the 1871 one, rose in the lower parts of the Nawoon to over 3½ feet higher. The point of highest excess was found near Mageelaha, the 87th mile, having thus passed down the river over 40 miles with the extension of the embankment 21 miles. Undoubtedly here the embankment was the principal cause of this elevation; but did any other cause intervene? In 1877 the very highest flood ever known on the Irrawaddy and on the Nawoon came down. The excess height over that of 1871, which was 1·34 feet at the Nawoon entrance gradually increased through 3 and 4 to over 5 feet, the highest point being found near Mageelaha as before. The breaches made in the work in 1876, had been filled, and urgent appeals were made for more money to raise and strengthen the works, but little money was available, and it came late. What there was was at once used in strengthening the upper embankments where the greatest agricultural extensions had been made, and the lower part, from the 47th mile southwards, was in much the same position as in the 1876 flood. It is needless to say there were many breaches. One occurring just behind Mageelaha where the gauge is recorded, may have had some effect in lowering the record; but as it was, the height of the 1877 flood was over 5 feet above that of 1871. Here both the embankment works and the immense rainfall concurred to produce these results, as well as the increased discharge from the Irrawaddy.

Re-enumeration of the causes and modifying agencies of the floods.

75. Enumerating the various causes contributing to or influencing these effects we have:—1st. The sources of supply; including the Irrawaddy and the local watersheds of the Nawoon; 2nd. The moderating agencies, including the plains on the river banks and the river channel itself; 3rd. The rainfall; and 4th the embankment works. Rigorously, the third should be classed with the first; and the fourth with the second; but in the actual examination of the several parts no rigorous classification can be adhered to. The river channel must be examined together with the Irrawaddy supply; and the moderating plains with the watershed area.

Features of the Nawoon River.

76. The Nawoon river follows in its general direction a straight line drawn approximately southwest from Thambyading as far as the mouth of the Daga. On either side of this as an axis the course of the river winds; the length of the straight line being 70 miles while that of the channel in the same distance is 127 miles. It is a curious feature of this river that there is hardly an island in its whole course from Thambyading until near the Daga. The channel is clear and well shaped, nowhere breaking out into side channels or broad and shallow reaches. It is not, however, to be inferred that it continues always in the same course. On the contrary, it wanders continually over the country in its immediate neighbourhood; forming, occasionally, abandoned lagunes. Islands sometimes appear as the moving channel opens up a new path across a small bend, but they exist for only a short time, being either carried away entirely like one lately existing near Kyoukyua, or becoming annexed to the opposite bank, when the new course is fully established. The process of excavation of its banks is carried on with moderate activity, much less so than on the Irrawaddy; and, though no measurements have been made, its waters appear far less charged with silt. Its curves perpetually change, but at a slow rate. The total fall of the 1871 flood surface was nearly 40 feet in the 127 miles, or, measured from the

Nawoon entrance, 37 feet in 133 miles. The rate of fall diminishes in general, as is common on all rivers, with its seaward progress. Thus taken on the Thambyading course we have the following average surface slopes between the stations.

Flood Surface fall of the River.

Table 34.

Station.	Mile.	Distance.	1871 Flood Levels.	Fall.	Rate per mile.
			× M. S. L.	Feet.	
Thambyading ...	0		47·00		
		8		5·56	0·695
Myogwin	8		41·44		
		22¼		9·28	0·422
Leymyethna ...	30¼		32·16		
		12½		4·38	0·344
Zimbyogong ...	42¾		27·86		
		21¾		5·57	0·256
Ngathaingyoung ...	64½		22·29		
		22½		5·90	0·262
Mageelaha	87		16·39		
		11		3·43	0·312
Zubingwin	98		12·96		
		9½		3·34	0·352
Taboo	107½		9·62		
		8½		1·15	0·135
Shoaynyoungbin ...	116		8·47		
		11		0·61	0·056
Daga	127		7·86		

As already mentioned there is uncertainty about the height the 1871 flood would at present take at Thambyading, as extensive changes have occurred there; and there is also uncertainty about the flood marks to the south of Ngathaingyoung; but the errors are small, and corrections would not change much the rates given. These rates are abnormally high in the upper portion of the river, and indicate an unsettled régime. In the intermediate part the fall is moderate and more regular; but is liable to be changed and increased should any cut-offs take place across the bends. In the lower part of the river the mean sea level is approached, although the distance from the sea is still over 100 miles. Here the slope becomes very small.

77. The low water level was marked on the river gauges. These were established at the inspection bungalows built simultaneously with the embankments. The caretakers of the bungalows record the river height daily or oftener. In the lower part of the river the flood and ebb tide is also recorded. From the entire observations it appears that the very lowest water known occurred in the year of the greatest flood height, 1877. In this the Nawoon records agree with those of the Irrawaddy. The period of lowest water extended through February and March. The following table gives for the various stations the heights above mean sea level of the 1877 flood, and of the 1877 low water, with the difference in feet, or the range of the river. It also gives the range of the tide from low to high water on the days when the lowest point was marked; all measurements except column 2 are in feet.

Low water levels of the river and range from high to low water.

Table 35.

1 Name of Station.	2 Mile by river from sea.	3 1877 flood height.	4 1877 low water height.	5 Range or difference.	6 Tidal range same date.	7 Greatest tidal range 1877.
Thambyading	229	48·36	8·36	40	0·00	0·00
Myogwin	221	44·26	6·20	38·06	0·00	0·00
Leymyethna	198¾	35·41	4·16	31·25	0·00	0·00
Zimbyogong	186¼	31·86	2·19	29·67	0·17	1·13
Ngathaingyoung	164½	26·62	−1·21	27·83	1·50	2·08
Mageelaha	142	21·51	−1·74	23·25	2·92	4·17
Zeebingwin	131	14·98	−2·27	17·25	1·83	3·67
Taboo	121½	10·62	−3·92	14·54	3·08	3·92
Shoaynyoungbin	113	9·47	−4·00 (?)	13·47	...	....
Daga	102	8·56	−4·00 (?)	12·56	...	...
Bassein	90	...	...	...	...	7·35

The last column shows the greatest tidal range with the spring tides, which are generally felt most powerfully in April and May. At this time the river surface is higher than in March, usually two to four feet, so that the high tide of May ranges some feet higher than the difference above indicated, above the extreme lowest water. The Bassein record is taken from a self recording gauge fixed on the iron wharf at that place in 1872 and 1873. The high flood of 1871 rose about 2½ to 3 feet above the spring tide of May; but the levels have not been carried from the embankments to Bassein.

Peculiarities of the levels and of its tides.

78. The heights given for the low water of 1877, with the tidal ranges on the same date, indicate that the mean low water line in the part of the river from Mageelaha to Bassein was two or three feet below mean sea level. This cannot be correct. The explanation of this anomaly is most probably to be found in an error in the levels brought by Colonel Stoddard from the Railway levels at Prome, as a similar discrepancy was found on the Irrawaddy side at Donabyoo and Pantanau, where the low water is shown as below mean sea level. The Grand Trigonometrical Survey levels give a difference of over four feet higher than the Railway levels. When the error is corrected the whole of the embankment levels given can be altered. But any such alteration as is possible will only show that, at low water, the river surface is nearly horizontal for a distance of nearly 150 miles from the sea. To this point the tide ebbs and flows, the water actually flowing up stream. The influence of the tide is felt much further; but, in ordinary circumstances, is hardly recognizable above Zimbyogong, 186 miles from the sea. In high springs it causes a rise in the river surface there of over one foot, but neither there nor at Ngathaingyoung is there any trace of an upward flow, at any time of the year. In the floods no tidal flow is perceptible in any portion of the river except in the neighbourhood of the Daga and southwards. The backing up of the water and stoppage of its flow is marked above the Daga mouth; and at Bassein itself in the floods of August and September 1872 the gauge there recorded a rise and fall of 4½ feet in ebb and 6½ feet in spring tides.

Division of the river into three portions with distinctive characters.

79. The degrees in which the tidal influence is felt, taken in conjunction with the heights of the river surface above mean sea level, give rise to a natural division of the river into three distinct portions, each possessing marked characteristics. From the mouth of the Daga to the sea,

over 100 miles off, the tide has free play at all seasons, except perhaps in its upper end in extreme high floods like those of 1875 and 1877. There is no bore in the river, or none that has ever caused remark. This lower hundred miles of the Nawoon, which is generally known as the Bassein River, is a true estuary of the sea. Its mouths have a total width of 2 or 3 miles, into which an immense volume of water pours with each tide, keeping the channel well scoured, and returning to the sea with the added burden of the river discharge, which is assisted in its flow by the slight elevation of flood surface at Bassein above the mean sea level. The estuary gradually narrows down to about ½ a mile in width near the Daga. Its depth is comparitively great, the channel being clear and deep close to each bank; and, as soundings are thus unnecessary, little accurate information is available regarding its depth throughout. Few islands are found in its course, and the whole length of the estuary up to the Daga forms a magnificent harbour. The banks in the neighbourhood of Bassein are lined with mills and various buildings.

The lower portion.

80. From the mouth of the Daga northwards the second division of the river stretches to beyond Mageelaha, over some 50 miles, in which in all but high floods the tide is felt. In ordinary low water there is here an ebb and flood flow which exercises most important influence on the shape and dimensions of the channel. The range of the river surface from ordinary flood height to ordinary low water is about 10 feet near the Daga mouth; and under 20 near Mageelaha, but the extreme ranges are 12½ feet and 23¼ feet at those places. The range varies gradually at the intermediate stations. The rise and fall of the tide reaches about four feet in springs in the lower reaches, and lessens towards the upper. The precise place where the upward flow terminates cannot be determined, and probably varies much with the tides, but does not reach far above Mageelaha. From this portion, at all points higher up, the water has a continual flow seawards; somewhat checked at high tides in the lower reaches, but never turned; while it is never felt at Leymyethna. This length of the river from near Mageelaha to the Thambyadeing entrance constitutes a third part of the river, differing in many respects from the two others, while it is capable of further sub-division by distinctive characteristics, as will shortly be shown. The range of the river surface increases steadily with the distance from the sea, so that the 23¼ feet difference at the 142nd mile becomes 30 at Zimbyogong the 186th, 38 at Myogwin the 221st mile, and 40 at the entrance from the Irrawaddy, nearly 230 miles from the sea.

The middle portion.

The upper portion.

81. If we neglect the marine estuary from the Daga mouth southwards, the principal characters of the different parts of the river may be inferred from the following table.

Characters of the upper and middle portions of the Nawoon.

Table 36.

1	2		3	4	5	6	7
Number of Section.	Position on River from Thambyading.		Width at top of banks.	Greatest depth in 1877 flood.	Greatest depth 1877 extreme low water.	Area of flood 1877 cross section in S. feet.	Area of low water cross section.
1		Mile 0	700	94	54	42,240	17,640
2		1	458	72·00	33·00	18,925	4,534
3		3	420	61·06	23·00	19,694	5,612
4		8	600	70·09	32·03	37,201	17,981
Thapangyo M Station		10	830	47·23	10·36	31,388	5,773
4 a		16½	723	48·00	12·00	17,216	1,580
4 b		24	419	48·00	14·00	15,475	2,604
5	Leymyethna.	31	830	41·36	10·11	25,356	2,544
6		34	594	58·41	27·53	23,540	6,649
7		36	407	52·20	21·55	15,589	4,754
8		39	484	47·91	17·66	14,999	1,326
9		43	488	39·04	9·37	15,774	2,156
10		46	506	69·16	40·74	22,228	9,354
11		50	523	46·57	17·48	20,192	5.749
12		63	1270	67·36	39·36	51,291	17,131
13	Nga-thain-gyoung	65	614	42·22	14·39	23,312	7,254
14		70	442	63·34	36·51	21,528	9,911
15		73	460	85·30	59·14	25,550	14,040
16		78	452	45·35	20·35	16,774	15,749
17	Mageelaba	87	1227	54·96	31·71	40,307	12,628
18		92	1020	40·71	20·25	33,733	14,296
19		95	897	44·95	26·08	37,944	21,744
Measuring station	Zeebingwin	98	1100	32·25	15·00	40,407	22,640
20		102	1128	44·86	28·61	35,984	17,963
21	Taboo	108	1508	41·66	27·12	37,356	24,466
22		116	974	72·88	59·41	48,590	35,693
23		118	773	68·33	54·83	21,471	11,319
24		118	1080	60·49	46·59	37,523	22,830
25		119	1322	48·04	34·84	36,862	19,557
26		120	1800	60·94	47·84	43,771	25,300
27		121	1800	57·36	44·29	52,161	44,894
28		122	720	59·71	46·74	34,372	25,235
29		123	1240	63·13	50·16	43,771	28,466
30		125	1222	48·81	36·05	32,136	16,811
31		126	730	65·03	52·37	30,568	21,580
32		127	1050	40·81	28·25	33,900	21,026
33		127	2676	34·90	22·34	62,544	32,865

82. The Table is drawn up from the dimensions of several cross sections of the river taken in the years 1877 and 1878, with the addition of a few added in 1879, (4*a* and 4*b*), and the principal measuring stations. In all 37 cross sections are given, distributed pretty uniformly over the rivers course. They were almost all measured at low water in the usual way. A line was selected in a straight reach, normal to the current, and a measured base line set off at the end of it. A boat was allowed to drift across the section line, a man sounding the bottom with a lead all the time. When he was signalled as on the line he read the depth. His position on the section was marked by observers with instruments at the ends of the base line. The height of the water in the river at the time was measured with the level from the nearest flood mark; and the gauge readings at the contiguous stations permitted corrections and reductions to be made.

Method in which the Table of dimensions was compiled.

83. The dimensions given in Table 36 are all referred to the high flood and extreme low water of 1877. The drawings show the same cross sections, mostly with the measurements actually made, which differ from those of the lowest water level in the Table. The position of each cross section is given in column 2. The top width, the greatest flood and low water depths, with the flood and low water areas are given in the remaining columns. A first examination of the results shows a great difference in the cross sections of the upper and the lowest parts of the course, corresponding to the division according to the tidal and non-tidal portions of its channel. The difference is more noticeable in the top widths of sections, and in the areas, especially those of low water, From the Daga River to Mageelaha the width of the river ranges from 700 to 1,800 feet; the average of the sections given being over 1,200 feet. From Mageelaha northwards the widths of the channel, excluding sections 1, Thabingyo, 5 and 12, some of which are what are called false sections, range from 400 to 600 feet. The average width, including all these sections but the 1st, is 586 feet. The flood water areas of the lower division of the river range generally very much higher than those of the upper division; the averages, excluding as before No. 1 section, being 39,000 square feet for the lower, 24,000 square feet for the upper. In the areas of the low water cross sections the contrast is still more remarkable, as from Mageelaha southwards the average is over 23,000 square feet, while northwards it is about 7,500 square feet, or less than one third.

Comparison of the dimensions of the river in the upper and middle portions.

84. The differences noticed are solely due to the free play of the tide during the dry weather months in the lower half of the channel, a fact which is well worth considering by those who allege that the flow of tidal water in a river channel has little or no influence upon it. The flood levels given in Table 34 prove from the variations in the rates per mile in the two portions considered that no influences in the scouring action of the water during flood can account for the enormously increased capacity of the lower division of the channel. Here the rates of fall vary from 0·056 to 0·352 feet per mile; while in the upper the variation is from 0·256 to 0·695 feet, bringing with it a vastly increased scouring power. The incessant ebb and flow of the dry weather tide cannot but have an immense effect in continually abrading the channel lining, and in raising and distributing it through the mass of the water; while the dry weather discharge of the river itself must cause a transportation of this silt-bearing water to lower and lower positions. If we possessed a complete set of measurements of the estuary in continuation of the river to the south of the Daga, a still greater contrast would be observable in the channel dimensions, which suddenly increase with the ebb and flow of the flood tidal waters, to over half a mile in width and correspondingly increased areas, which also can only be due to the free play of the tide at all seasons in this part.

The scouring effect of the tide on the river.

85. The sub-division of the cross sections of the upper trunk of the river is into the Thambyading group to the north of the junction of the rivers, and those belonging to the Nawoon main channel to the south of it. The differences on which this depends are not immediately apparent from the Table. Only four sections are there shown for the eight miles of the Thambyading channel. Of those the first was taken on the funnel shaped entrance close to the Irrawaddy, and is abnormally large. The fourth was taken close to the junction with the Nawoon, and is in a measure a false section, and therefore also abnormally large. The great discrepancy of size found between nearly contiguous sections of a river channel is a fact familiar to those who have had much acquaintance with rivers flowing through soil readily susceptible to excavation. When erosion is in progress it almost always occurs only on one bank, a deposit taken place upon the other. The two processes are rarely equal on the same cross section as the earth is transported lower down the channel. It thus often happens that as the channel enlarges on the one side with the erosion it does not diminish in a corresponding degree on the other, and there is a portion of the cross section occupied by slowly-flowing or dead water or eddies flowing backwards. This is a false section; and, if measured with a view of finding the discharge, gives a false notion of the capacity of the channel.

Further sub-division of the upper portion into two parts.

False sections of rivers.

86. Sections No. 2 and 3 are fairly representative of the capacity of the Thambyading. They show 18,925 and 19,694 square feet of cross section for the 1877 flood. The sections on the trunk from Thabingyo to Mageelaha vary much in size; but it is noticeable that some of these range from 14,000 to 17,000 square feet, indicating a capacity much less than that of the Thambyadeing, supposing, in both cases, each set to be equally representative, and when it is remembered that the 1871 flood surface fall on the Thambyadeing was nearly 0·7 feet per mile while that of the trunk south of it in no place exceeded 0·425 feet the discrepancy in the capacities of these portions of the channels is much enhanced. The degree in which the surface falls affects the flow of a stream is a matter of dispute amongst Hydraulicians, but all are agreed that an increased slope brings with it an increased mean velocity to a river. When, further, the accessions of water from the old Nawoon entrance, and from the southern watershed areas which discharge into the Nawoon south of Thabingyo are considered, it is obvious that the length of river channel from the 10th to the 80th mile near Mageelaha is wholly incapable of carrying within its banks anything like the flood discharge furnished to it by its various feeders, and that, irrespective of the action of the embankment works, it must have inundated the whole of the contiguous country unless a complete change in its capacity or in the supply were brought about.

The Thambyading river channel and the trunk of the river.

87. How this state of things arose will be readily understood from the measurements made on the Thambyading and Nawoon entrances on the Myanoung embankment line at different periods. Cross-sections of these are given in Plate XIX. Mr Fennessy, in 1864 or 1865, took the first sections; and others have been made since at the same places, thus enabling a comparison to be made of the changes. The Nawoon cross-sections do not give a fair idea of the extent to which this opening has closed; as the site of the section is over half a mile from the Irrawaddy, and the immediate opening at the bank is much more largely filled with sand than at the measuring place. But even there the section is shown to have diminished from 14,000 to 10,000 square feet in the interval from 1864 to 1875. It now only commences to flow in moderately high flood. In 1864 the Thambyading entrance had a width of 175 feet, a depth of 32 feet, and a cross-sectional area of 3,612 square feet. In 1869 it was 350 feet wide, 51 deep, with area of 10,906 square feet. In 1874 it measured 400 feet wide, 63 deep, with 16,720 square feet in area. A further measurement was made in 1875, but the erosion of the Irrawaddy had then approched

Changes in the Nawoon and Thambyading entrances.

so close that the entrance had taken a funnel shape, with an exaggerated cross-section of over 40,000 square feet. The position of this section is shown on Plate XIX by a line AB. A second line CD was measured in 1875, a little below the other. This gave a width of 428 feet, a depth of 72 feet, and an area of 18,770 square feet to the 1875 flood line. These results correspond with those of No. 2 and 3 above.

Great enlargement of the Thambyading branch.

88. The whole of the Thambyading river must have progressively enlarged in a corresponding degree with that of the entrance. The diminution of the Nawoon entrance by no means kept pace with this enlargement; as the closing of this opening had been in a great measure finished before any development of the Thambyading from its original state as an insignificant creek took place. And the measurements show that at present the Thambyading has in itself alone a larger capacity than the old Nawoon ever had after receiving almost all its accessions of discharge. It is to be regretted that a similar set of measurements on all the cross-sections, or on a large number are available to show the nature of the changes in the several divisions of the Nawoon; but no engineering staff could be spared in the earlier days of the embankment for that work. The few measurements at hand, however, prove that up to 1875 the Thambyading has for several years been continuously and enormously enlarged; while there is every reason to believe that the trunk from the junction to Mageelaha has also been continuously enlarging but at a much slower rate; while there is no evidence of any kind to show that alterations have taken place in the capacity of the river channel below Mageelaha.

Moderate enlargement of the trunk.

Longitudinal profile of the river.

89. The points now brought to notice regarding the top widths and capacities of the different parts of the channel are of the very highest importance in considering the effects of the embankment works upon the floods. The longitudinal profile of the thalweg of the river and its co-relation with the lateral curvature may now be briefly noticed. The profile of the river bottom was taken by soundings, and the depths were connected with the gauge records at the nearest stations, and made to read from the lowest water of 1877. The method most generally followed was to anchor a small boat in a known position in the centre of the strongest current. A light cord with floats at every 100 feet or larger distances was then allowed to run out loosely from the boat and was stretched by the pull of the water. It always followed the line of the current. The depths were then taken at each float. The positions of these were fixed by points on the banks. The observations were all made in the low water time of the dry season.

Inferences from the profile.

90. In the tidal part of the river the method of following a drifting rope proved less useful than in the trunk, as the continually changing set of the current removed the line of soundings from the true thalweg, and the result often showed a smaller depth than is to be found in that part of the river. It would have served better at high flood. As it is, the results are of value in showing that generally the tidal part is less subject to the continually recurring pools and bars found in the upper river, and the depth is uniformly greater at low water in the former part of the channel. The position of the bars is generally at the tail end of the erosion where the stream leaves the one bank to cross to the other. These bars have much influence in regulating the flow of the water in the river, as they tend to hold back the bottom water in the deep pools higher up.

Survey and large scale plan of the Nawoon.

91. A complete survey has been made of the Nawoon from the Thambyading entrance to the Daga. This is given on a large scale in Plates XXIV to XXVIII. The river, in its lateral variations, has formed several large bends; and traces of abandoned portions of channel are met with at various points. The embankment follows the present river line pretty closely except when it has

been found expedient to go across the neck of a few of the bends, or to follow the bank of an old part of the channel. The three largest bends occur:—from the 15½ to the 19th mile of the river channel where the embankment reaches across in less than half a mile; from the 41½ to the 44½ mile of embankment where the river course describes 12½ miles; and from the 56th to 59½ miles where the river has a detour of 8½ miles over the same distance. These bends, as well as the smaller ones on the river, are made up of a large number of curves of contrary flexure, and varying in extent. As is well known, the erosive action of a river nearly always takes place on the convex side of the channel at each curve.

Curves and bends on the river.

There is an example of a contrary action on a considerable length of the Irrawaddy below Maoobin, but such cases are rare, and due to local peculiarities. As a rule the radius of curvature of these curves is small compared with those of the Irrawaddy; but they are to be found of all dimensions from nearly complete semicircles of a furlong radius to great sweeping reaches of the river with the centre of curvature at almost infinite distance. It is difficult to assign any fixed relation between the lateral curvature of the channels and the vertical variations of the river surface.

92. The direction of the Nawoon channel has been stated as approximately southwest from Thambyading. This place stands about 16 miles from the nearest points of the base of the Aracan Hills, and 34 from their crest. The general direction of the mountain chain is nearly due north and south. The river would thus soon strike against their base were it not for the fact that a local deviation towards the southwest commences in this neighbourhood; and the narrowing of the base which accompanies the lowering of the crest going southwards permits a plain of four or five miles in width to interpose between the river channel and the hilly land in all that part of its course from the junction to Mageelaha; or from about the 8th mile to the 80th or 90th. From the 78th to the 87th miles the river makes a great bend to the westward, and touches in the lower part the high land running down from the hills. This is the third bend before referred to where the embankment makes a short cut across, following the bank of an old channel, and leaving some two miles in width of low plain land over which the spill waters flow in flood. The river water is thus not confined to the channel in this part; but it soon becomes nearly so at Payagyee, about 3 miles below Mageelaha, at the 63rd mile of the embankment and the 90th of the river; where the embankment runs close to the channel on the left side, while moderately high cliffs terminated by a large Pagoda are washed by the river on the right bank. Here for the first time the flood waters are almost completely restricted to the river; and in this fact, which is one of cardinal importance in the record of the changes of level of the river surface, is to be found the explanation of the extraordinary and persistent rise of the river in the 1876 and 1877 floods. It is extremely fortunate for the success of the embankment works that this restriction commences below the narrow trunks of the river, and in the broader and more capacious tidal part. This will be more apparent when the records of the floods are examined.

General direction of channel.

Arracan Sub-Yoma Plains on right bank.

Hilly land approaching river channel at Payagyee on the right bank.

93. In describing the divisions of the river it was noted that the demarcation between the parts of dry weather tidal flow and continuous down flow of discharge was somewhere in the neighbourhood of Mageelaha. As a gauge has been regularly recorded at this place, which is sufficiently near to Payagyee to permit the records to serve for the river there, the division point of the river and the approach of the embankment and the hills to the river channel may be assumed to approximately coincide; and the variations there to be represented by the Mageelaha records. The other two divisions of the river have a distinct dividing point, at Songong, just opposite Myogwin, where the Nawoon and Thambyading unite

Gauge records at dividing point of river channel.

and where a river gauge is regularly recorded. This is at the 8th mile of the river measured from Thambyading. At the 9½th mile is the measuring station of Thapangyo, where the discharges of the Nawoon have been taken. A gauge is fixed there, but only recorded when the velocities of the water are being measured. It is found by making a suitable correction that the Myogwin gauge approximately represents the alterations of river surface at Thapangyo.

Watersheds of the Nawoon.

94. The local watersheds of the Nawoon River are naturally divided into portions corresponding with the divisions of the river. No drainage enters this part of the Nawoon from the left bank. On the right bank, from the Daga to Payagyee, the country is mostly hilly. Some plain land lies between the projecting spurs which break it up into isolated tracts, and prevent any flow of the spill parallel to the river, although at times a portion of the plains serve to moderate the flood. Roughly measured the area of the whole of the mountain slopes and plains draining into the tidal part of the Nawoon amounts to about 250 square miles. From Payagyee to the measuring station at Thapangyo the drainage from about 900 square miles of lands enters the Nawoon. All the torrent streams to the immediate south of the Okpho choung unite to flow into the river by the Kyoukyua choung just below Thapangyo. The plain land also to the west of the old Okpho channel drains into the Nawoon in this second division of the rivers course. The total extent of mountain land is about 680 square miles, while 220 are plain land, most of which is at a level several feet below the river flood surface, and is thus of great service in moderating the floods; but the portion to the north of Thapangyo is not available for the purpose, as it receives most of its water from the northern sources of the river.

Sources of the Nawoon.

95. These sources, which have hitherto been so variable, are now likely to be definitively determined. They consist of the watershed draining into the Nawoon to the north of Thapangyo and of the contributaries from the Irrawaddy. The former will in future consist of the Mamya and Okpho torrent streams, and of the Myanoung Plain; the whole of the drainage of which will be directed into the Nawoon by the second scheme of reclamation works for that plain. The watershed areas are, as before given, the Mamya basin, 105 square miles; the Okpho basin 215 square miles; and the Myanoung Plain with 530 square miles. As has been seen, the whole of the drainage from this does not now come into the Nawoon at any stage but high flood, when a certain amount of spill from the Irrawaddy also finds its way over the banks between Loodauzoo and Thambyading.

The Irrawaddy contribution of supply to the Nawoon.

96. The Irrawaddy contribution consists in the dry weather of the amount brought by the Thambyading. In floods it also sends the spill just referred to, as well as a certain amount through the Nawoon. The bank between the Nawoon and Thambyading entrance has been nearly all embanked; but a small amount of spill comes round this and adds to the total volume. It has been related how it was found practically impossible to measure all these several sources of supply separately, and how no alternative was open but to take the measurements of the united volume at Thapangyo, one and a half miles below the junction of the streams. The next section will give a description of those measurements and the results obtained.

SECTION III.

The discharges of the Nawoon River.

Institution of measurements for discharge.

97. The measurements for discharge on the Nawoon River, were instituted in 1872, at the same time as those on the Irrawaddy, for the purpose of supplementing the measured discharges at Saiktha and Zaloon. The embankment works were then in course of extension on both rivers, but the enquires made related rather to the problem of double embankments for the Irrawaddy than to any contingencies in the Nawoon resulting from the works. And if even full attention had been given to the latter case, it was not possible, with the establishment available, to carry out such a complete set of investigations on the smaller river, as alone would have sufficed to lead to practical results of value, in permitting anticipations to be framed of the effects likely to ensue from the prolongation of the embankments. It was with extreme difficulty that three separate measuring parties were spared to carry out even the measurements made, as the establishment at disposal was reduced almost to the lowest limit sufficient to carry on the new works and to maintain the old. Whenever the insufficiency of the data available for leading to a just conclusion comes to notice, and to those skilled in such investigations as the present, this will constantly recur, it is to be remembered that it would take a very large staff indeed to collect simultaneously all the data requisite, and that it has only been by over-working a comparitively small staff that the present results were obtained. Such as they are, they are larger in extent than those collected for any other river, so far as has been published, including even the magnificent results of the labours of Humphry and Abbot on the Mississippi, contained in their great Report which gave the example to this work.

The Thapangyo Station and the reasons for choosing it.

98. The reasons that determined the selection of the Thapangyo site for a measuring station for the Nawoon have been already narrated; but may be again briefly stated. It was impossible to spare sufficient skilled observers to measure the different contributing channels above Thapangyo; nor, in flood time, when the spill passed over the Irrawaddy bank near Noukmee, would it have been practicable to measure this at any point higher than Songong, where the Thambyading and Nawoon unite, as the spill water after inundating the country finds its way into the Nawoon along the whole line of its banks above that place. Between Songong at the 8th mile of river and the entrance of the Kyoukyua torrent stream at the 11th mile in which portion of the river it was necessary to fix the station, the only tolerably straight length occurred at the 10th mile; about the middle of which the embankment approaches closely to the river bank. This alone would have been a strong reason for the selection, as no spill can escape on the left side; but when with this is conjoined the fact that the station lies in the middle of the straight reach where the lateral motion of the channel appears least; and that a tolerably high bank is found in front of the village which permitted a base line to be raised above high flood, this spot, notwithstanding several disadvantages, appeared indisputably better than any other that could be chosen.

Selection of a cross section.

99. On the position being settled the cross section was taken in a line normal to the current in the usual manner, surface floats were thrown in, their paths were observed from a temporary base line, and were plotted on a large scale on paper. A line at right angles to the mean direction of these was drawn, and then transferred to the ground. A base line 200 feet long at right angles to this was marked out on the bank and raised; small huts for the observers being built at either end. Long and stout

pegs were driven into the ground and made level at the end of the base. Into these brass nails were fixed to mark accurately the positions for the theodolites. On the opposite banks tall posts were placed to mark out the upper and lower section lines. Only the lower line was used for the purpose of calculation.

Gauge heights at the measuring station,

100. A bench mark was fixed on the bank and connected by levellings with the gauge at the Myogwin Inspection Bungalow. The 1871 flood at the latter read 41·44 + M. S. L, at Thapangyo it read 40·67 + M. S. L. Before this was determined the gauge there had been fixed to read 40 feet at 42·12 + M. S. L. This gauge was used in 1872 and 1873. The observations have since been reduced to correspond with a gauge reading 40 feet at the 1875 flood height. This stood at 42·42 feet + M. S. L. at the Thapangyo gauge. By a mistake the observations made in 1878 were taken with a gauge fixed to read 40 feet at 42·79 feet + M. S. L; but these have since been reduced, as all the others, to correspond with the 1875 flood mark. The 1877 flood read 43·85 feet + M. S. L. at Thapangyo.

Increase of area of the Thapangyo cross section from 1872 to 1878.

101. In taking the cross section of the river, an operation which was at first performed at intervals of a month, but afterwards once a week, the gauge reading of the water surface was noted, the depths were measured from a drifting boat with a common lead line when the boat crossed the section, the position of the cord on the section line being observed with the theodolite. The results were plotted from time to time. Cross sections of these for the years 1872, 1875, 1877, and 1878 are given in Plate XXIV, where the cross sections are shown separately with all details; and combined in one figure in profile (figs. 2 & 3). The 1872 section is that of the 9th September, when the top width, measured from the theodolite station was 567 feet, and cross sectional area to the level of the 1875 flood was 20,980 square feet. During the years 1872 and 1873 the width and area varied slightly, the current showing a tendency to set towards the right bank. From 1873 to 1875, there was a great increase in width and in area. The former had increased from 567 to 670 feet; the latter to 24,116 square feet, or by no less than 3136. By February 1877 the width was 780 feet, the area 26,077 square feet. In July 1878 the width of the river on this same section line had increased to 830 feet, and its area measured from the 1875 flood level was 29,667 square feet.

Exact comparisons practicable between these areas.

102. The whole of the increase in width and in area was due to an erosion of the right bank, towards which the current had steadily set since 1873. The observing stations were on the left bank; and, as the original ones have been retained throughout, the measurements made admit of exact comparison. It was in every respect most undesirable to remove the place of observation on account of the changing section; more especially as the whole of this part of the river was undergoing similar changes. The enormous increase in the size of the Thambyading must have had much influence, by throwing into the Nawoon river channel a larger body of water, in causing these changes in the cross section at Thapangyo. But whether these increases of area indicate decided increases of capacity in the channel are points that can only be determined by the velocity measurements, and the discharges computed from them. It is to be noted that the depth of the deepest portion of the channel changed very little during this period; but what change there has been is a shallowing of 2 or 3 feet from 1872 to 1878.

Velocity observations at Thapangyo.

103. The velocity observations upon the Nawoon were made at first in the same manner as those at Saiktha upon the Irrawaddy. Double floats were used; the lower one a wooden cylinder 6 inches in diameter and one foot long weighted just to sink in water, the upper of light wood 6 inches diameter and one inch deep, and these were adjusted so that the centre of the lower float was at one or more metres in depth from the surface, the connection being made with

a fine cord. A series of from 25 to 30 of these, each one metre in depth were thrown in from a boat sailing across stream above the upper section, and the position of the float on each section line and its times of crossing were observed. This gave the interval of time in which the float traversed the distance between the two sections, which were 200 feet apart. The line of the part actually travelled was rarely truly perpendicular to these sections; and therefore, the distance run by the float was somewhat over 200 feet. But the variation was small on the average; and any correction made for this deviation in the velocities, would entail a corresponding correction in the cross sectional area in the opposite sense; as the velocity would be increased in the first case; and the area would be diminished in the second. The two errors thus compensated each other. (1) But this deviation of the floats from the path they might be expected to follow is common on all rivers, and is an evil which increases with the width between the section lines; and which militates against giving an increased distance to run as advocated by several able writers. On the Nawoon it produced a further evil. In addition to the 30 surface floats, ten sets of floats were thrown in from a boat anchored above the upper section line. These floats were arranged in depths increasing metre by metre from one metre till the bottom was reached. It was always possible to tell when the last float touched the bottom; by the little flag in the upper float constantly dipping and recovering itself. It was intended to take the velocities on ten vertical lines and combine these with the surface velocities to educe the volume of water discharged. But in the 1872 observations it was found in practice that, although the floats were dismissed from the anchored boat in truely vertical order at about 50 feet above the upper line, or 250 from the lower they never arrived at the lower line in the same order. A considerable commotion was evidenced in the water, which deviated some floats to one side, some to the other of the surface float. This commotion was observable all through the cross-section, but mostly so at the sides. The result was that the sets of floats were diffused through a considerable area, and might represent the mean velocity of this area, but could certainly not be accepted as giving that of a vertical line.

Selections from the records of the velocity observations. Surface velocities.

104. A selection from the 1872 record book will give an example of the method of working and illustrate the peculiarities described. From the date 9th September 1872 the following extract is made.

Soundings along lower Section Line gauge reading 37·50 at Thapangyo. September 9th 1872.

No of Sounding.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
Angle with base line from Notrh end.	4 10	19 31	26 56	27 33	32 57	38 35	44 35	48 2	54 44	59 30	63 32	67 43	68 17	69 45	70 35
Distance from base line.	14 0	70 8	101 6	104 2	129 6	139 4	197 0	222 3	282 9	339 5	4017	488 0	502 1	542 1	567 1
Depth in feet.	0	26	30	31	32	32	38	37	43	45	46	44	40	24	0

The soundings numbered 1 and 15 are on the edge of the water. On the same day the following observations were made for surface velocity; the gauge reading as before. The time was recorded by a pendulum marking half seconds.

(1) Since this was written a curious confirmation of these views is to be found in Lieutenent Harman's Paper on the measurements of the River in Assam, Asiatic Society of Bengal Journal for 1879, where after working out the calculations by the method of making the double allowance indicated, he discovers and proves that they exactly balance; and that he might have followed the simpler method.

Number of surface float.	Angle with north end of base Line.	Time in half seconds by pendulum.	Time of passing from 1st to 2nd section line.	Distance traversed.	Velocity in feet per second.	Distance from south end of line.	Wind.
	° ′						
1	14 54	399	199½	200	1·0025	53	½
2	17 41	246	123	200	1·6260	64	½
3	25 39	106	53	200	3·7736	96	½
4	30 50	98	49	200	4·0817	119	½
5	36 58	91	45½	200	4·3962	151	½
6	38 46	88	44	200	4·5454	160	½
7	40 41	93	46½	200	4·3001	172	½
8	42 0	86	43	200	4·6512	180	½
9	46 58	85	42½	200	4·7059	214	½
10	48 33	77	38½	200	5·1948	227	½
11	51 45	86	43	200	4·6512	254	½
12	51 16	85	42½	200	4·7059	249	½
13	53 53	83	41½	200	4·8193	274	½
14	56 58	83	41½	200	4·8193	307	½
15	59 45	74	37	200	5·4054	343	½
16	60 31	79	39½	200	5·0633	354	½
17	61 43	72	36	200	5·5555	372	½
18	62 26	74	37	200	5·4054	383	½
19	64 53	76	38	200	5·2631	427	½
20	64 51	81	40½	200	4·9383	426	½
21	66 42	79	39½	200	5·0633	464	½
22	66 57	95	47½	200	4·2105	470	½
23	68 21	96	48	200	4·1666	504	½
24	68 33	97	48½	200	4·1237	509	½
25	69 28	119	59½	200	3·3614	534	½

Sub-surface Velocities.

105. Mr. Richard, who was in charge of this velocity station and personally superintended the earlier operations, was unable to devote more time in one day than sufficed to take the foregoing observations. He therefore alternated days of surface and sub-surface velocity measurements. On September the 10th, the following sub-surface observations were made. Gauge reading at Thapangyo 37·33.

Number of Float.	Angle with base line from north end.	Time in half second.	No. of seconds in passing from 1st. to 2nd section line.	Distance traversed.	Velocity in feet per second.	Distance from south end of base line.	Wind.	Remarks.
	° ″							
1	24 25	132	66	200	3·0303	91	N ¾	$\frac{W}{V}$=0·929
2	23 28	124	62	200	3·2258	87	N ¾	
3	24 46	133	61½	200	3·2520	92	N ¾	Depth of water 25 feet.
4	23 00	146	73	200	2·7397	85	N ¾	
5	23 55	173	86½	200	2·3121	89	N	
6	22 57	138	69	200	2·8985	85	N	
7	20 25	177	88½	200	2·2598	75	N	
8								
				Average	2·8169	86 b		Touched.
		2ND ANCHORAGE						
1	30 13	92	46	200	4·3178	121 b	N 1	$\frac{W}{V}$=0·899
2	32 47	95	47½	200	4·2105	129 c	N 1	
3	32 30	97	48½	200	4·1237	127 b	N 1	Depth of water 31 feet.
4	29 33	95	47½	200	4·2105	113 b	N ½	
5	29 57	99	49½	200	4·0405	115 b	N ½	
6	31 0	99	49½	200	4·0405	120 b	N ½	
7	30 58	97	48½	200	4·1237	120 b	N 1	
8	31 50	102	51	200	3·9215	124 b	N 1	
9	33 12	103	51½	200	3·8835	131 c	N ½	
10	31 4	114	57	200	3·5088	120 b	N ½	
11	30 57	111	55½	200	3·6036	120 b	N ½	
12	31 1	107	53½	200	3·7383	120 b	N ½	
13	32 25	101	50½	200	3·9604	127 b	N ½	
14	31 33	112	56	200	3·5714	123 b	N ½	
15	32 37	121	60½	200	3·3057	128 c	N ½	
				Average	3·9060	123 b		
		3RD ANCHORAGE						
1	38 24	96	48	200	4·1666	159 c	N ½	$\frac{W}{V}$=0·977
2	39 21	90	45	200	4·4444	164 c	N ½	
3	36 37	97	48½	200	4·1237	148 c	N ½	Depth of water 32 feet.
4	40 32	91	45½	200	4·3962	171 c	N ½	
5	40 16	88	44	200	4·5454	169 c	N ½	
6	38 7	101	50½	200	3·9604	157 c	N ½	
7	39 0	97	48½	200	4·1237	162 c	N ½	
8	37 22	95	47½	200	4·2105	153 c	N ½	
9	38 43	100	50	200	4·0000	160 c	N ½	
10	39 19	105	52½	200	3·8095	164 c	N ½	
11	39 39	107	53½	200	3·7383	166 c	N ½	
12	37 26	95	47½	200	4·2105	153 c		
13	40 6	98	49	200	4·0405	168 c		
14	39 11	107	53½	200	3·7383	163 c	N 1	
15	39 18	113	56½	200	3·5398	164 c	N 1	
				Average	4·0692	161 c		

4TH ANCHORAGE.

Number of Float.	Angle with base line from North end. °	″	Time in half second.	No. of seconds in passing from 1st to second section line.	Distance traversed.	Velocity in feet per second.	Distance from south end of base line.		Wind.		Remarks.
1	48	5	83	41½	200	4·8193	223	c	...		$\frac{W}{V}$=0·883
2	46	57	88	44	200	4·5454	214	c	...		
3	50	39	81	40½	200	4·9383	243	c	...		Depth of water 33 feet.
4	49	26	94	47	200	4·2553	233	c	N	¼	
5	48	42	88	44	200	4·5454	228	c	N	½	
6	47	44	90	45	200	4·4444	220	c	N	½	
7	48	13	96	48	200	4·1666	224	c	N	½	
8	48	51	98	49	200	4·0817	230	c	N	½	
9	49	40	95	47½	200	4·2105	235	c	N	½	
10	48	30	108	54	200	3·7037	227	c	E	½	
11	49	9	97	48½	200	4·1237	231	c	E	½	
12	48	6	90	45	200	4·4444	223	c	E	½	
13	48	25	97	48½	200	4·1237	226	c	E	1	
14	48	20	105	52½	200	3·8095	226	c	E	1	
15	48	8	110	55	200	3·6363	223	c	E	1	
					Average.	4·2565	227	c			
				5TH ANCHORAGE.							
1	54	23	88	44	200	4·5454	278	d	E	1	$\frac{W}{V}$=0·939
2	54	28	85	42½	200	4·7059	280	d	N	1	
3	50	28	87	43½	200	4·5977	242	c	N	1	Depth of water 42 feet.
4	52	29	91	45½	200	4·3962	260	d	N	½	
5	52	12	93	46½	200	4·3011	257	c	N	1	
6	52	30	90	45	200	4·4444	261	d	N	1	
7	54	9	94	47	200	4·2553	277	d	N	1	
8	53	48	91	45½	200	4·3962	273	d	N	½	
9	50	55	95	47½	200	4·2105	246	c	N	1	
10	50	41	92	46	200	4·3478	244	c	N	½	
11	52	51	98	49	200	4·0817	263	d	N	½	
12	52	44	94	47	200	4·2553	262	d	N	½	
13	53	5	91	45½	200	4·3962	266	d	N	½	
14	52	18	113	56½	200	3·5398	259	d	N	½	
15	52	46	111	55½	200	3·6036	263	d	N	½	
					Average.	4·2718	262	d			
				6TH ANCHORAGE.							
1	53	54	81	40½	200	4·9383	274	d	N	½	$\frac{W}{V}$=0·941
2	57	28	80	40	200	5·0000	313	d	N	½	
3	57	46	83	41½	200	4·8193	317	d	N	½	Depth of water 44 feet.
4	57	50	79	39½	200	5·0633	318	d	N	½	
5	58	18	83	41½	200	4·8193	324	d	N	½	
6	56	35	83	41½	200	4·8193	303	d	N	½	
7	56	59	89	44½	200	4·944	308	d	N	½	
8	57	16	85	42½	200	4·7059	311	d	N	½	
9	56	24	91	45½	200	4·3962	301	d	N	½	
10	57	20	91	45½	200	4·3962	312	d	N	½	
11	56	19	93	46½	200	4·3011	300	d	N	½	
12	58	35	85	42½	200	4·7059	327	d	N	½	
13	57	12	86	43	200	4·6512	310	d	N	½	
14	57	51	90	45	200	4·4444	314	d	N	½	
15	57	52	97	48½	200	4·1237	318	d	N	½	
					Average.	4·6452	316	d			
				7TH ANCHORAGE.							
1	58	58	81	40½	200	4·9383	332	d	N	½	$\frac{W}{V}$=0·967
2	60	13	78	39	200	5·1282	349	d	N	½	
3	59	51	74	37	200	5·4054	344	d	N	½	Depth of water 45 feet.
4	59	48	79	39½	200	5·0633	343	d	N	2	
5	61	0	79	39½	200	5·0633	360	d	N	½	
6	61	25	81	40½	200	4·9383	367	d	N	½	
7	61	32	84	42	200	4·7619	369	d	N	½	
8	59	52	89	44½	200	4·4944	344	d	N	2	
9	61	32	86	43	200	4·6512	369	d	N	2	
10	60	26	86	43	200	4·6512	352	d	N	½	
11	58	12	91	45½	200	4·3962	322	d	N	2	
12	60	52	87	43½	200	4·5977	359	d	N	2	
13	59	15	83	41½	200	4·8193	336	d	N	2	
14	60	28	92	46	200	4·3478	353	d	N	½	
15	60	28	91	45½	200	4·3962	353	d	N	½	
					Average.	4·7768	351	d			

Number of Float.	Angle with base line from North end.	Time in half second.	No. of seconds in passing from 1st to second section line.	Distance traversed.	Velocity in feet per second.	Distance from south end of base line.	Wind.	Remarks.
			8TH ANCHORAGE.					
	° ″							$\frac{W}{V}$ =0·966.
1	62 4	80	40	200	5·0000	377 d	N ½	
2	62 58	78	39	200	5·1282	392 d	N ½	Depth of water 46 feet.
3	62 56	82	41	200	4·8780	391 d	N ½	
4	62 35	80	40	200	5·0000	386 d	N ½	
5	62 15	83	41½	200	4·8193	380 d	N ½	
6	63 55	82	41	200	4·8780	408 d	N ¼	
7	62 53	78	39	200	5·1282	391 d	N ½	
8	63 30	80	40	200	5·0000	401 d	N ½	
9	63 28	84	42	200	4·7619	400 d	N ½	
10	63 35	83	41½	200	4·8193	402 d	N ½	
11	64 23	84	42	200	4·7619	417 d	N ½	
12	64 14	85	42½	200	4·7059	414 d	N ½	
13	63 28	80	40	200	5·0000	400 d	N ½	
14	62 56	92	46	200	4·3478	391 d	N ½	
15	63 43	94	47	200	4·2553	404 d	N ¼	
				Average.	4·8322	390 d		
			9TH ANCHORAGE.					
								$\frac{W}{V}$ =0·907.
1	65 22	83	41½	200	4·8193	436 e	N ½	Depth of water 45 feet.
2	66 47	86	43	200	4·6512	466 e	N ¼	
3	66 60	84	42	200	4·7619	449 e	N ¼	
4	67 42	95	47½	200	4·2105	487 e	N ¼	
5	65 36	81	40½	200	4·9383	441 e	N ½	
6	65 25	94	47	200	4·2553	437 e	N ½	
7	66 36	104	52	200	3·8461	462 e	N ½	
8	66 10	94	47	200	4·2553	453 e	N ½	
9	67 29	91	45½	200	4·3962	482 e	N ½	
10	65 46	96	48	200	4·1666	444 e	N ¼	
11	65 46	95	47½	200	4·2105	444 e	N ¼	
12	66 0	89	44½	200	4·4944	449 e	N ¼	
13	65 24	94	47	200	4·2553	437 e	0	
14	66 37	101	50½	200	3·9604	462 e	0	
15	66 41	92	46	200	4·3478	464 e	0	
				Average.	4·3713	461 e		
			10TH ANCHORAGE.					
								$\frac{W}{V}$ =1·067
1	67 41	115	57½	200	3·4783	487 e	0	Depth of water 44 feet.
2	67 27	100	50	200	4·0000	481 e	0	
3	68 2	100	50	200	4·0000	495 e	0	
4	68 46	99	49½	200	4·0405	514 f	0	
5	67 33	99	49½	200	4·0405	483 e	0	
6	67 44	113	56½	200	5·5398	488 e	0	
7	68 23	102	51	200	3·9215	504 f	0	
8	67 35	92	46	200	4·3478	485 e	0	
9	68 25	111	55½	200	3·6036	505 f	0	
10	67 22	127	63½	200	3·1496	479 e	0	
11	68 46	123	61½	200	3·2520	515 f	0	
12	68 45	122	61	200	3·2787	514 f	0	
13	67 30	112	56	200	3·5714	483 e	0	
				Average.	3·7095	495 e	0	Touched.

On the 10th September 1872 the surface floats were repeated. The observations were as follows:—

Number of Float.	Angle with base line from north end.	Time in half second.	No. of seconds in passing from 1st to 2nd section line.	Distance traversed.	Velocity in feet per second.	Distance from south end of base line.	Wind.
	° ′						
1	19 55	253	126½	201	1·5731	72 b	S 3
2	28 6	117	58½	201	3·4261	107 b	S 3
3	30 33	113	56½	201	3·5577	118 b	S 3
4	31 51	103	51½	200	3·8835	124 b	S 3
5	35 0	96	48	200	4·1666	140 c	S 3
6	41 26	93	46½	200	4·3011	176 c	S 3
7	40 43	89	44½	200	4·4944	172 c	S 3
8	41 14	91	45½	200	4·3962	175 c	S 3
9	45 59	90	45	200	4·4444	207 c	S 3
10	48 30	86	43	200	4·6512	227 c	S 3
11	51 34	89	44½	200	4·4944	252 c	S 3
12	53 42	91	45½	200	4·3962	272 d	S 3
13	54 10	88	44	200	4·5454	277 d	S 3
14	58 35	79	39½	200	5·0633	327 d	S 3
15	60 46	79	39½	200	5·0603	357 d	S 3
16	59 5	80	40	200	5·0000	334 d	S 3
17	61 9	81	40½	201	4·9383	363 d	S 3
18	62 23	86	43	201	4·6512	382 d	S 3
19	63 18	88	44	201	4·5454	398 d	S 3
20	64 46	90	45	201	4·4444	424 d	S 3
21	65 14	93	46½	201	4·3011	433 e	S 3
22	66 8	89	44½	202	4·4944	452 e	S 3
23	68 15	112	56	202	3·5714	501 f	S 3
24	68 32	109	54½	202	3·6697	509 f	S 3
25	69 13	141	70½	202	2·8652	527 f	S 3
					Distance to Bank 56 feet.		

Anomalies and irregularities in the observations.

106. When the observations were first instituted the point of crossing was observed on both the upper and on the lower line; but as the former was not required in the further calculations it was afterwards left unrecorded. In the record of the float observations of 10th September, it is noticeable that in some of the positions of the anchored boat the floats reach the lower line in widely differing positions. Thus in the 9th anchorage floats 1, 6 and 13 cross at 436 and 437 feet from the base, while floats 4 and 9 cross at 487 and 482 feet, thus differing by from 45 to 51 feet. Similar differences are found in the other anchorage floats. Now, on a river between 500 and 600 feet broad, 50 feet is a considerable part of the width, and the rates of the different depths of the current on a vertical line at that distance apart may vary much; so that the rate of the surface velocity to the average of the whole from the surface to the bottom on a given vertical $\frac{v}{W}$ is not accurately shewn by the figures obtained from the actual

velocities observed. It was therefore considered inexpedient to continue both surface and sub-surface velocities at the Thapangyo measuring section; and after September 1872, and during the 1873 and the 1875 observations, only the sub-surface velocities from 10 boats were taken; it being thought better to keep on these, as giving a truer mean of the river velocity in each sub-division of the area than surface floats above. In 1878 the older method of measurement both by surface floats and by sub-surface ones was resumed; and; with the exceptions above noted at Thapangyo, all the observations made, both on the Irrawaddy and on the Nawoon included both surface and sub-surface floats. It is thought that the latter method is to be preferred as the surface floats give but slight additional trouble to take; and can introduce no error even if they bring little increased accuracy. The calculated discharges for the 1873 and 1875 floods are perhaps not quite so close to truth as those of 1872 and 1878 in consequence of the difference of method; but are sufficiently trustworthy for all practical purposes.

Method of dividing cross sections into sub-areas.

107. Premising then that the complete set of observations both of surface and of sub-surface floats is to be recommended and should always be used, the method of dealing with them for the Thapangyo station in 1878, will be described. Several of the daily series of surface float velocities were taken indiscriminately from all stages of the river during observation and collated together with their distances from the base line. Thus for the 19th June 1878 we have: gauge reading 14·20.

Float No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Distance from base.	105	106	108	148	187	212	277	294	364	414	475	523	558	594	630	657	688	717	..	768
Velocity.	1·33	1·50	1·57	1·62	1·74	1·83	2·17	2·22	2·35	2·46	2·38	2·56	2·43	2·35	2·43	2·32	2.22	2·12	..	1·38

For the 13th July 1878. Gauge reading 33·97 feet.

Float No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Distance from base.	97	119	150	127	156	186	215	254	296	377	433	484	561	591	614	640	645	681	717	700
Velocity.	2·12	2·35	2·70	2·77	2·63	2·39	2·98	3·22	3·27	3·50	3·57	3·57	3·50	3·39	3.27	3·17	3·12	3·22	2·63	2·43

For the 7th August 1878. Gauge reading 38·17 feet.

Float No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Distance from base.	56	100	154	182	132	145	168	220	360	342	335	374	369	372	445	493	550	570	605	610	587	655	634	650	655	691	703	729	747	709
Velocity.	2·29	2·32	3·57	3·57	3·27	3·27	3·57	4·00	4·54	4·44	4·54	4·65	4·76	4·76	4·87	5·00	4·5[illegible]	4·76	4·87	4·87	5·12	4·65	5·00	4·65	4·87	4·34	4·25	4·16	4·76	3·70

For the 13th September 1878. Gauge reading 37·79 feet.

Float No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Distance.	116	103	158	129	121	134	166	174	192	221	203	226	234	336	339	415	399	431	456	485	500	478	524	547	549	608	636	676	687	774
Velocity.	2.27	2·74	3·44	3·57	3·39	3·63	3·57	3·50	3·70	3·63	3·70	3·84	3·77	3·77	3·92	4·16	4·34	4·34	4·00	3·77	4·65	4·16	4·16	4·08	4·34	4·54	4·16	4·16	4·16	2·63

The velocities are observed to increase from the sides towards the *thalweg*, the greatest velocities generally being found in the interval from 400 to 700 feet. It is not intended at present to enter into any study of the relation of the velocities and depths; and all theoretical or other questions foreign to the immediate practical object in view will be relegated to the further report. The sole aim now is to present the facts and the operations actually used on the Nawoon river; and though these continually trench on a most interesting ground, all that is not absolutely necessary to that purpose will be avoided. After arranging a

large number of the observations in the above manner, the cross section was subdivided into intervals according to the agreement of the velocities with each other in these intervals. It was ultimately found that the velocities could best be arranged in six groups A, B, C, D, E and F which fell in the distances 0 to 100, 100 to 200, 200 to 400, 400 to 550, 550 to 650 and 650 to 830 from the base line. These served fairly both for the higher and the lower stages of the river. The corresponding areas were calculated out; at first for the 40 feet gauge reading; and, subsequently, for each lower gauge reading, by simply deducting the rectangular upper areas of each sub-section from these. A specimen of the observation and calculation is given in appendix II where one weeks entries are recorded. The first series of columns in the calculations gives the areas, gauge readings and dates.

Further selection from observations in Appendix.

108. The second series of columns contains the surface velocities falling within the respective areas. These are arranged in due order and a mean is struck for each sub-section, on each day. When no velocity falls within any given sub-section, which happens rarely owing to there being from 20 to 30 floats, and only 6 sub-areas, a mean is taken of the corresponding velocities of the day before, and the day after. The mean velocity thus found is a first multiplier for each sub-area.

Method of taking means of surface velocities.

109. A second multiplier is obtained from the sub-surface velocities in the third division of the page. Before entering this, however, they require arrangement under two processes. The first consists in finding the mean of the whole from the floats from each boat, and dividing this by its own surface velocity. The result gives the ratio which the average of the whole velocities on each vertical or nearly vertical line bears to that at the surface; and by assuming that similar ratios subsist all through the various sub-sections to those actually found we have 30 vertical lines of velocities in addition to the 10 taken, from which to deduce the discharge. In practice this does not readily appear, as the tendency is to reduce the number of figures employed by taking the means for each sub-seetion to obtain a single second multiplier. And as when these ratios are struck and collated there appear variations amongst them, not only from the side to the *thalweg* of the stream, ; but in each sub-section on the same day, a further average is struck for each sub-area for several days, the number in each case being determined by the state of the river. When this continued pretty constant, as in the week given, the average was taken for the six days of observation for each part; and these averages form the multipliers finally used in connection with the mean velocities before obtained.

Method of taking means of sub-surface velocities.

110. In the fourth and last series of columns the process of multiplication by logarithms is performed; the figures being given in each case in full, so as to be readily scrutinized and checked. Up to this stage all the operations have been with figures in cubic feet per second; and the results are now converted into cubic metres per day; the logarithm of conversion being 3·38853. The object in making this converson is less to save figures in summing up the daily discharges in cubic feet than it is to bring the result into a form where they are susceptible of comparison with the numerous river discharges published by continental Engineers. The subject of river hydraulics has rarely been treated in English; and most of the data accessible are given in the metrical measure. The fact that a cubic metre of water weighs nearly a ton suggests the term metre-ton for the designation of the results.

Final calculation of discharge.

111. On the completion of the calculations for discharge the several quantities obtained on each occasion were arranged with a view to make a comparison of the capacity of the river in the years 1872, 1873, 1875 and 1878. The computations had in each case been made from the gauge readings recorded;

First comparison of discharges at Thapangyo for the years 1872 to 1878.

and, as the 40 feet datum points of the three periods, 1872-3, 1875 and 1878 differed somewhat, the first step taken was to bring the whole to a common datum, that where the 40 feet agrees with the high flood mark of 1875 ; which has now been determined on for most of the stations as the standard, although subsequent floods have risen above it. On collecting the results according to common gauge readings it became apparent that there has been a progressive increase in the discharge of the Nawoon at Thapangyo for all gauge readings since 1872 and up to 1878, when they were last made. But there were, in some cases, considerable variations in the discharge for the same gauge standing in each year ; and it was necessary in order to obtain a clear and accurate notion of what that increase was, to devise a means of bringing out the results of comparison in definite figures.

Construction of discharge scales for the different years at Thapangyo.

112. To this end scales of discharge were constructed. These scales are given with the fullest detail in the appendix ; and in plate XXIII. The first proceeding was to plot out on separate sheets on a large scale, the whole of the discharges for each year as vertical ordinates to the gauge readings for the 1875 datum as co-ordinates. These are given on a smaller scale in plate XXIII ; where the whole are shown in one sheet. It is obvious on examining these that they delineate roughly of themselves a line with concave curvature upwards, which has a more or less regular progress from the lowest to the highest figures. Numerous attempts were made to discover the law of this progress both for the Irrawaddy and for the Nawoon discharges. And, approximately, such a law was discovered, which is the same nearly for the large river and for the smaller one. Thus the 1872 scale, which is the only complete one on the Nawoon, as no discharges were measured in other years for stages below 12 feet on the gauge, shows that a straight line represents better than any others the discharges taken between 13 feet and 25 feet on the gauge. A similar straight line also serves for the other years' observations on the Nawoon between nearly the same points. Both above and below this however there follows a quintic parabola, or a parabola of the 5th order ; and no other curve than this will serve to pass through the series of points so as to be useful for interpolation ; or to represent an average of the results. It was only after repeated failures to compel other curves to answer that these quintic parabolas were obtained. They were roughly found by analysis by taking the 1st, 2nd, 3rd, 4th and 5th differences and then built up by synthesis to their present forms. It was necessary to employ similar curves for the 1873, 1875 and 1878 observations, curves of lower powers failing to pass through the points. The Irrawaddy scaled curves differ somewhat from these. The 1872 one is a very flat common parabola from the 8th foot of the gauge to the 27th foot, differing slightly from a straight line. At both ends of this lies a quartic parabola. No other line would so well represent the law of increase.

The scales attempt to give the average discharge for each year.

113. In every case the sharper curves join the intermediate flat lines by inosculation ; so that there is no abrupt transition in the rate of increase. For the Irrawaddy it was found expedient to calculate out one curve for the rising stages of the river ; and one for the falling stages ; as there is an appreciable increase in the former over the latter at all gauges. These scales were used for working out the discharges of the Irrawaddy for the entire period during which gauge records have been kept. At first it was intended to do the same for the Nawoon ; and similar rising and falling scales were prepared. But it was evident that the continuous change in the discharge of the river for successive years precluded this means of showing the results ; and the observations themselves were not so numerous nor concordant ; nor, on the whole, so satisfactory for the earlier observations on the Nawoon as on the Irrawaddy. It has therefore been determined to strike only an average scale for both rising and falling stages for each year. This permits a larger percentage of difference with individual observations than if the two scales were used ; but as no other

purpose is required from it than a comparison of the different years discharges, one will serve this end better than two would, as it gives a truer mean for the year. The calculated scale curves, with a comparison of the discharges obtained by them, and the results of direct measurements are given in the Appendix.

Observations in the discharge scales.

114. In the case of the 1872, the 1875 and the 1878 observations the scale curves pass pretty fairly through the mass of the observations, the differences on both sides balancing each other nearly. This is readily seen in the drawings in Plate XXIII. The 1873 observations do not agree so well with the curve for that year and they are much more irregular amongst themselves than those of other years. No observations were taken for the 1873 flood season before June, when the gauge stood at 29 feet and as there had been little change of section in the dry weather it may be assumed that the curve below 29 feet resembles closely that for 1872. Above 29 feet, the scale curve requires to preponderate unduly over that of 1872 to at all represent the 1873 discharges; and though it is throughout lower than the curve of 1875, the increase in the interval from 1872 to 1873 is greater generally than in the two years 1873 to 1875, especially in the higher gauge readings. No reason is known why this should be the case. The writer, who was in charge while the 1872, 1875 and 1878 observations were in progress, had frequent occasion to check and control these; but he was absent from the country while the 1873 ones were taken and can offer no explanation of the irregularities observed. The measurements were, however, made mostly by the same persons as the 1872 and 1875 ones; and should therefore be equally reliable. But as the interval from 1872 to 1875 is equal to that from 1875 to 1878, and the observations made in these years were more numerous and complete, and extended over a longer time and greater range of the gauge readings than in 1873, these three years scale curves will be used for purposes of comparison. The 1875 and 1878 scales have been drawn on the lower part of Plate XXIII, from the same co-ordinates as that of 1872, which permits a ready comparison by the eye; and the discharges for each foot of the gauge from 13 feet to 40 feet for the three years, with their corresponding differences, are shown in Table 37 below.

Irregularities noticeable.

Table 37.

Comparative Table of discharge Scales.

Discharge scales of the Nawoon River at Thapangyo for the years 1872, 1875 *and* 1878.

Gauge Reading.	1872. Discharge in Metre tons.	Difference 1872 and 1875.	1875. Discharge in Metre tons.	Difference 1875 and 1878.	1878. Discharge in Metre tons.	Difference 1872 and 1878.
8	13,360,040	.....	.....	.....	.....	.....
9	15,570,240	.....	.....	.....	.....	.....
10	18,206,800	.....	.....	.....	.....	.....
11	21,396,800	.....	.....	.....	.....	.....
12	25,290,360	.....	.....	.....	.....	.....
13	29,380,480	.....	.....	.....	.....	.....
14	33,470,600	529,400	34,000,000	2,000,000	36,000,000	2,529,400
15	37,560,720	1,439,280	39,000,000	3,000,000	42,000,000	4,439,280
16	41,650,840	2,349,160	44,000,000	4,000,000	48,000,000	6,349,160
17	45,740,960	3,259,040	49,000,000	5,000,000	54,000,000	8,259,040
18	49,831,080	4,168,920	54,000,000	6,000,000	60,000,000	10,168,920
19	53,921,200	5,078,800	59,000,000	7,000,000	66,000,000	12,078,800
20	58,011,320	5,988,680	64,000,000	8,000,000	72,000,000	13,988,680
21	62,101,440	6,898,560	69,000,000	9,000,000	78,000,000	15,898,560
22	66,191,560	7,808,440	74,000,000	10,000,000	84,000,000	17,808,440
23	70,281,680	8,718,320	79,000,000	11,000,000	90,000,000	19,718,320
24	74,371,800	9,628,200	84,000,000	12,000,000	96,000,500	21,628,700
25	78,461,920	10,538,700	89,000,620	13,009,880	102,010,500	23,548,580
26	82,555,880	11,457,140	94,013,020	14,049,980	108,063,000	25,507,120
27	86,678,000	12,400,120	99,078,120	15,152,880	114,231,000	27,553,000
28	90,893,560	13,392,880	104,286,440	16,357,060	120,643,500	29,749,940
29	95,329,280	14,468,660	109,797,940	17,703,560	127,501,500	32,172,220
30	100,193,800	15,668,060	115,861,860	19,132,140	135,094,000	34,900,200
31	105,798,160	17,038,400	122,836,560	20,977,440	143,814,000	38,015,840
32	112,576,280	18,633,080	131,209,360	22,864,140	154,174,500	41,598,220
33	121,105,440	20,510,940	141,616,380	25,208,120	166,824,500	45,718,060
34	132,126,760	22,735,620	154,862,380	27,702,620	182,565,000	50,438,240
35	146,565,680	25,375,080	171,940,600	30,424,400	202,365,000	55,799,320
36	165,552,440	28,499,160	194,051,600	33,325,900	227,377,500	61,825,060
37	190,442,560	32,179,540	222,622,100	36,333,400	258,955,500	68,512,940
38	222,837,320	36,492,500	259,329,820	39,338,180	298,668,000	75,830,680
39	264,604,240	41,516,020	306,120,260	42,195,740	348,316,000	83,711,760
40	317,897,560	47,328,380	365,225,940	44,722,560	409,948,500	92,050,940

Increase in the capacity of the channel proved by the scales.

115. This Table gives an immediate and definite account of the progressive increase in the capacity of the Nawoon at this station. The 1872 scale is the most accurate one for the lower gauge readings, as the number of observations were much larger in that than in subsequent years in the dry season. The 1875 ones do not go below 15½ feet, nor the 1878 ones below 13

feet, while those for 1872 were carried on to the lowest stage of the river at 8 feet. Again, the 1875 record is the most accurate for the highest reading of 40 feet; as observations were continued till that point of the gauge was reached in that years flood; while in neither of the other years did the river reach 39 feet on the gauge. On making allowances for slight errors in striking the true average scale for each years discharge it will be seen that from every stage from 13 feet upwards the increase is by regular and equal increments for each half foot until about 24 or 25 feet, when a more rapid increase takes place. The second interval of three years shows a somewhat higher ratio of increase for the different gauge readings than the first. Thus at 14 feet, the difference from 1872 to 1875 is about 500,000 tons, while from 1875 to 1878 it is 2,000,000. At 25 feet of the gauge the first increase is shown higher than the second, as it reaches as high as 47 million tons in the one case, and 45 millions in the other. When compared with the actual discharge of the Nawoon in 1872 these quantities vary from 15 to 20 per cent of the total daily discharge; and indicate a steady increase for all stages of the river of at least 5 per cent yearly for six years in succession on the 1872 discharge. This ratio of course falls much when the comparison is made with the 1878 discharges; but even here the yearly ratio in some cases reaches 15 per cent.

Explanation of the enlarged capacity of the Nawoon at Thapangyo.

116. The enormous enlargement of the Thambyading entrance to the Nawoon affords a sufficient explanation of this increase in the discharge at Thapangyo. It appears conclusive that the construction of the embankment works can have had no influence whatever on the results, so far as these are considered confined to the increased discharge *for the same gauge readings.* Thapangyo is situated at the 13th mile of the embankment just near the point where the Nawoon changes its direction from east and west to south-westerly, and the very wide plains to the north and east of this point permit a free expansion of spill water in high flood; while it is obvious that for all gauge readings below the crest of the bank, that is, say below 36 or 37 feet, the embankments do not affect the discharges in any way. And the Nawoon embankment was constructed as far as the 25th mile in the season before the 1872 measurements were commenced, so that there has been no change in these in the neighbourhood of Thapangyo to correspond with the increased discharge. The subsequent extensions of the works southward have doubtless in some measure modified the discharge even at Thapangyo; but this has been principally by raising the whole surface of the river throughout the part affected; which causes greater discharge on any given section, *but with higher gauge readings.*

The Thambyading enlargement is the sole cause.

117. There is no probability of any of the other sources of the Nawoon having contributed in any degree to the enlargement in the capacity of the channel. The Nawoon entrance itself has rather diminished its supplies; while there is no evidence of the rainfall in the torrent basins, or on the Myanoung plain having increased. The flood spill over the low bank to the north of Thambyading has certainly much increased with the erosion of the high ground on the edge, and the cutting off of half a mile or more of the end of the Myanoung embankment; but as this water after flowing over the country mostly enters the Thambyading river above Thapangyo, this supply is really part of that river's contribution, and should be considered together with it. At present the water passes over the bank while the Irrawaddy stands at 26 feet on the Henzada gauge, or 27 feet at Thapangyo, and the first instalments are drained into the Thambyading by the Sinpong choung. As the river rises higher the water flows slowly southwards and enters the river channel at all points along its bank. This portion of the discharge is a most important one and will probably increase until the erosion ceases near Loodauzoo; but it can only affect the river in high flood.

The contribution of discharge from the Irrawaddy over the Noukmee bank.

118. As the discharge scales show, the increase is as great in proportion for the gauge readings below 27 feet at Thapangyo as for those above. This implies that the river is excavating its channel at all stages and with all quantities of water discharged. There can be no doubt but that in this it follows the variations that have taken place in the Thambyading entrance from its first opening from the Irrawaddy to its junction with the Nawoon. The comparison of the cross sectional areas near the opening made in the last section proves that an immense development of capacity has occurred in this from 1865 to 1878; and this more than suffices to account for the increased size of the united river at Thapangyo. It is evident also that had measuring observations for discharge been made at this station in 1865 and 1869, when the earlier cross sections at Thambyading were taken, the results would have shown a similar progressive increase in the discharge there at all stages of the river, from 1865 to 1872, as has taken place since the last date.

Increased capacity at all stages of the river.

119. It remains to enquire what are the probabilities of the further increase of the river's capacity, and of its continuing to pour vastly swelling volumes of water yearly into the river lying between the Nawoon embankment and the Arracan hills, to be carried off again subsequently by the lower channel of the river. The elements from which a judgment on this point can be arrived at have been already stated out. They are too complex and, in some respects, too uncertain in their conditions to permit that judgment to take a precise and definite form. The whole history, past, present and future, of these changes in the Nawoon centres in that of the great bend at Thambyading. The channel of the Irrawaddy, at a time ranging from 60 to 100 years ago, took a set westward on a small portion of its length about the neighbourhood of the village of Thambyading. The early history of this is unknown, but probably it had the form of one of the ordinary curves of the river, which gradually assumed a sharper curvature while the erosion on its convex sides increased. Every single curve is accompanied by others above and below, of opposite curvature; and while the one greater curve at Thambyading steadily pursued its course westward, two others attacked the eastern bank to the north and south. The old channel of the Irrawaddy got filled in as the curves changed position and a solid mass of land formed regularly in the wake of the western curve. This ultimately progressed 10 miles westward; the channel of the river being carried that much out of its course; the new land following and getting consolidated and covered with forests. The other two curves, one above and one below, after a time gave up these attacks on the eastern side and concentrated their effort on the root of the projection of this newer land, and they have for many years been ceaselessly advancing upon it.

Probabilities of further increase.

Recapitulation of past history.

120. The western curve got more and more acute within the period during which attention has been given to it; say since 1856; and after reversing the course of the old small channel at Thambyading leading from the Okpho torrent to the Irrawaddy, enlarged this in the manner already recorded. The westerly progress finally ceased in 1875; the principal westerly curve broke up into two others, one of which is still sweeping north eastwards and cutting off the embankment at Loodauzoo, the other is progressing southwards, and has now reached the old entrance of the Nawoon, which was almost closed during the changes of the channel. Opposite to the village of Thambyading, where the point of the westerly curve was, a totally new curve has formed, having an opposite or easterly convexity. This curve joins on to the two last mentioned, whose convexities are still to the west. The three form a series of almost half circles; and while there is a decided tendency of the two outer ones to move away from Thambyading, they all are increasing in size and in regularity of form. The writer finds it impossible, after careful and repeated surveys and personal examinations, to predict what this ultimate course will be. All that can now be said is, the northern one is just now attacking the bank on which the

Progress of the curves of the Thambyading bend.

embankment stands at Loodauzoo, but it is moving past it, while also its curvature appears enlarging. If, as there is reason to hope, it gets beyond this position within two or three years, the increase of flood spill from the Noukmee bank to the Thambyading will entirely cease, on the completion of the embankment; and this will remove one important source of the increased discharge at Thapangyo.

Changes at the Nawoon entrance,

121. The southern of the curves with a western convexity has commenced in the present year 1879, to attack the old Nawoon entrance. For an indefinite length of time a large sand-bank has lain before this, from 1000 feet to 2000 feet wide, sloping gradually upwards from low water to a considerable height at the opening. This has now disappeared, and the solid bank has begun to fall, the erosion having reached it. How far this will extend it is impossible to say. The curve moves on slowly, and enlarges. The latter change, while it widens the scope of its eroding action, lessens its intensity. Most likely the extreme end of the Nawoon channel will be cut off, and possibly the sand choking the entrance may be partially cleared out; but it is improbable that this channel will ever resume its former function as the principal source of supply to the Nawoon. Meanwhile, some small increase must be looked for in this direction; which, for reasons presently to be stated, will not increase much the capacity of the channel at Thapangyo.

Changes at the Thambyading entrance.

122. The cessation of the cutting action at Thambyading itself, and the formation of an obverse curve opposite the village has been attended with the usual results. Large deposits of the land have formed and are pressing in the lately active channel of the Irrawaddy. These are, at first, slips of sand of irregular form, which gradually by continual accretions become joined together, sometimes enclosing lagunes. The main channel of the Irrawaddy now flows at $\frac{3}{4}$ of a mile distance from Thambyading, and only joins the bank at the junction of the two curves about $1\frac{1}{2}$ or 2 miles below the entrance to the Nawoon. The interval is already occupied by high banks of sand covered with long grass and young trees. In the dry weather the only passage to the Nawoon is from the south inside a long tongue of land which completely diverts the Irrawaddy stream. To the north all the passages are closed. The continual flow of the water tends to keep this channel to the Nawoon open; but there can be no doubt that the expansion of the Thambyading river has reached its extreme limit; and that if any further change takes place here, it will be towards a lessening of the discharge and a closing of the entrance.

The Thambyading cut-off.

123. While there is a considerable degree of uncertainty about these three sources by which the Irrawaddy water reaches the Nawoon, a further uncertainty is introduced by the action of the two great eastern curves which continually operate on the root of the tongue of land occupying the centre of the bend. The lower of these has considerably less eroding power than the upper, which last advances rapidly on the ground, and threatens to cut it quite through in from 5 to 10 years. When once this result is attained a total change will occur in the conditions of the three means of supply to the Nawoon from the Irrawaddy. The main channel of the Irrawaddy will have left them far to the westward. The sudden change will permit the present main channel to remain open as a comparatively still lagune; and if the Nawoon and Thambyading entrances can be kept open they will continue to draw off a considerable supply, not so large, but yet comparable with that at present furnished. On the whole then it appears probable that there will still be an increase of discharge from the Irrawaddy to the Nawoon for two or three years longer; but that this will lessen and finally cease; that, as the erosion leaves the Noukmee Loodauzoo bank, the increment of flood supply from this quarter will be stopped, and cause a great diminution of discharge during high flood; that for the next few years the old Nawoon entrance

Conclusions regarding the anticipated changes on the supply from the Irrawaddy to Nawoon.

supply will slightly increase, but will have little effect upon the river; and that the Thambyading entrance itself, which has been the great disturbing factor in the system, has now finally ceased to increase, and though for some years the present supply by it may continue the only change here must be a diminution of the discharge.

The trunk of the Nawoon must continually increase in capacity, if even the sources of supply do not.

124. If even the present entrance for supply could be permanently retained without change, a continuous increase in the capacity of the Nawoon channel at Thapangyo measuring stations must be looked for for a time. This befalls it in common with the whole length of the Nawoon course from Thambyading to the tidal part below Mageelaha. It has already been shown that the Thambyading branch is at present considerably larger and more capacious than the trunk of the river lower down. This branch has not only a larger average sectional area of channel, but it has a considerably greater slope than the old channel. Both causes combine to bring a much larger supply than the Nawoon has been accustomed to receive, and than it can carry at stages corresponding with those at which it stood formerly when the Irrawaddy marked certain heights. The first tendency of the increased supply undoubtedly was to raise the Nawoon surface. If, for instance, the Nawoon at Myogwin near Thapangyo used to mark 25½ feet while the Irrawaddy at Henzadah marked 26; the change would probably be to make the Nawoon mark 27 instead of 25½. There would be an increased velocity of the current, and an increased scouring action; which would be combined till the Nawoon rose over its banks, when the spill flows to the plain lands to the west. But on the whole the total yearly erosion of the channel would be increased; and, being greatest at high flood, much of the silt would go with the spill water and be cast down in the lower plains. This process must continue until there is a greater equality between the capacity of the Nawoon throughout its trunk, and the quantity of water supplied to it, whether this equality results from a diminished supply, or from a sufficiently enlarged channel. The great rapidity with which the process can take place is evidenced by the Thambyading itself which has enlarged in all its length of 8 miles in the same proportion as the cross-section taken near the village of that name. On the other hand there is a contrary tendency at work.

Tendency of the capacity of the Thambyading to diminish.

125. This channel shows signs of lengthening out by continuous erosion of the convex sides of its curves. With each increase of length its rate of surface slope will lessen. And lessening slope will lower the capacity of the channel and of itself still an important means of reducing the supply. Thus if the fall of 6·33 feet in the 1871 flood on the 10 miles from Thambyading to Thapangyo was distributed over 15 miles, the slope would be reduced from 0·633 feet per mile to 0·422 feet; and the capacity of the channel nearly as $\sqrt{0·64}$ to $\sqrt{0·42}$ or as 8 to 6½ which would lessen the 1878 discharge of 348 million tons daily at 39 feet gauge to 283 millions or thereabouts. The slope of the river throughout its length tends towards equality, and such differences as now exist upon it cannot continue; the most probable solution being the lengthening out of the short upper channel just mentioned.

Measurments of discharge at different points of the Nawoon channel in 1878.

126. While on the subject of the capacity of the channel, the further measurements made in 1878 with a view to test the effect of the embankments upon the river may be described. It was desired to compare the discharge of the Nawoon at Thapangyo, the highest practicable place, and that at the lowest point to which the embankment works have reached. A second measuring station was chosen at Zeebingwin near the 71st mile of the embankment, almost at the end of the embankment; and a staff of observers was placed there for the month of August 1878, under the direction of Sub-Engineer Mr. Henry who had had much experience in this work at Zaloon in former years. A cross-section was taken and is given in plate XXVII. The velocities were measured in precisely the same way as at Thapangyo; 30

surface velocities, and 10 series of vertical velocities being taken. The section was clear and well defined. The observations were made for the month of August only. The results of the measurements are given in Table 38 side by side with those at Thapangyo in the same month.

Measurement Nawoon discharge at intermediate stations.

127. It was further desired to make comparisons of the discharge of the Nawoon at intermediate places; but it was not possible with the limited establishment available to add more sets of observers. The only alternative was to remove the two sets of observers from Thapangyo and Zeebingwin, which was done in September 1878. The former was placed at Leymyethna, the latter at Payagyee. Leymyethna is opposite to the 25½ mile of the Nawoon Embankment, and at the 30th river mile from Thambyading. At this place cross sections were made in the years 1875, and 1878, the latter being the one used for measuring. In 1875 the width was 810 feet, and the area 23,773 square feet. The cross-section is situated shortly below a sharp bend of the river; and formerly the current excavated a deep channel, which has since been filled without diminishing the capacity of the channel, as it was due to a local excavation. In 1878, when the stream velocities were taken, the width at the same place had increased to 860 feet; and the area to 25,462 square feet, thus showing that the river channel here had shared in the general enlargement of the upper trunk of the river. The two cross sections are shown in Plate XXIV. The station at Payagyee was near the 63½ mile of the embankment; and 90th of the river from Thambyading. It was situated at the part where the embankment neared the river opposite to the high ground closing on to the river right-bank. No previous measurement had been made here. The width was 848 feet and area of cross section 29,549 square feet. It is situated well within the tidal trunk of the river; the tides only flowing here during the dry weather, however. The result of the measurements at Leymyethna and Payagyee for September 1878 are given in Table 38. It was desirable to compare the Thapangyo discharge for the same period with these discharges; but by an oversight the gauge at Thapangyo, which is only recorded when measurements are in progress, had not been registered. On comparing the guage readings at Myogwin which is about 1½ miles by river from Thapangyo, with the record at the latter place for August 1878, it was found that the average difference in the record during 31 days, while the river rose and fell between 35 and 38 feet was only 0·07 feet in excess at the latter place. The river varied within the same limits in September; so that by adding 0·07 feet to the Myogwin record for that month, the Thapangyo gauge is closely approximated to. By the use of the 1878 discharge scale, the discharge of the Nawoon at the measuring station is given pretty nearly; and is sufficiently correct to permit comparisons to be made. In order to complete the result for each month, interpolations by simple arithmetical proportion according to the height of guage reading, have been made for the days when observations were wanting. These interpolations are marked in block letters. Before commenting on the figures given, which with those contained in Appendix II, are all that we possess for the discharges of the Nawoon, the altered condition of the river induced by the embankments shall be considered; and the peculiarities of the flood years noted.

Table 38.

Month and Date.	I Thapangyo, Gauge Reading.	I Thapangyo, Discharge in Metre tons per diem.	II Zeebinkwin, Gauge Reading.	II Zeebinkwin, Discharge in Metre tons per diem.	Difference between I and II.	Month and Date.	III. Thapangyo, Gauge Reading.	III. Thapangyo, Discharge in Metre tons per diem.	IV. Leymyethna, Gauge Reading.	IV. Leymyethna, Discharge in Metre tons per diem.	V. Payagyee, Gauge Reading.	V. Payagyee, Discharge in Metre tons per diem.	Difference between III and IV.	Difference between III and V.
August 1878. 1	37·23	263,210,400	37·08 *a*	273,998,370 *a*	+ 10,787,970	September 1878. 1	35·31 *a*	215,071,310 *a*	37·38	170,928,000 *a*	37·50 *a*	257,302,870 *a*	− 44,143,310	+ 42,231,560
2	37·43	277,327,400	37·67 *a*	276,444,800 *a*	− 882,600	2	35·53	219,820,100	37·33	166,828,500 *a*	37·42 *a*	256,039,150 *a*	− 52,991,600	+ 36,219,050
3	37·58	281,730,300	37·75	279,087,600	− 2,642,700	3	35·63	217,965,700	37·33 *a*	166,828,500 *a*	37·00	265,486,600	− 51,137,200	+ 47,520,900
4	37·65	285,815,000 *a*	38·00 *a*	284,479,700 *a*	− 1,335,300	4	35·87	232,876,640	37·33 *a*	166,828,500 *a*	36·83	264,996,400	− 66,048,140	+ 32,119,760
5	37·73	289,877,800	38·25	289,851,860	− 25,940	5	35·93	233,145,750	37.42 *a*	174,206,800 *a*	36·75	240,766,300	− 58,938,950	+ 7,620,550
6	37·87	288,825,800	38·67	296,775,750	+ 7,949,950	6	36·07 *a*	229,460,070 *a*	37·42 *a*	174,206,800 *a*	36·58	240,367,500	− 55,253,270	+ 10,907,430
7	37·87	299,494,800	39·00	287,063,730	− 12,431,070	7	36·27 *a*	235,410,270 *a*	37·58	187,322,000	36·25	239,599,400	− 48,088,270	+ 4,189,130
8	37·87	287,406,400	39·25	299,686,210	+ 12,279,810	8	36·51 *a*	242,550,510 *a*	37·67 *a*	193,298,530 *a*	36·17 *a*	220,469,140 *a*	− 49,251,980	− 22,081,370
9	37·77	285,080,800	39·42	297,461,700	+ 12,380,900	9	36·68 *a*	247,608,180 *a*	37·75	199,277,550	36·17 *a*	220,469,140 *a*	− 48,330,630	− 27,139,040
10	37·68	288,849,300	39·46	362,940,200	+ 14,090,900	10	36·77 *a*	250,285,770 *a*	37·83	199,150,370	36·33	258,979,660	− 51,135,400	+ 8,693,890
11	37·62 *a*	284,543,500 *a*	39·42 *a*	299,245,900 *a*	+ 14,702,400	11	36·77 *a*	250,285,770 *a*	37·85	209,686,870	36·58	265,706,000	− 40,598,900	+ 15,420,230
12	37·58	280,237,400	39·54	295,551,470	+ 15,314,070	12	36·68 *a*	247,608,180 *a*	37·98	205,467,000	36·92	276,324,200	− 42,141,180	+ 28,716,020
13	37·62 *a*	282,316,340 *a*	39·67	296,262,470	+ 13,946,130	13	36·51 *a*	242,550,510 *a*	37·79	205,781,000	37·25	270,108,550	− 36,769,510	+ 27,558,040
14	37·63	284,305,600	39·83	314,929,140	+ 30,533,540	14	36·37 *a*	238,385,370 *a*	37·75	197,572,410	37·50	284,568,600	− 40,812,960	+ 46,183,230
15	37·48	285,374,209	39·92	318,647,140	+ 33,272,940	15	36·27 *a*	235,410,270 *a*	37·71 *a*	197,552,860 *a*	37·67 *a*	284,787,640 *a*	− 37,857,410	+ 49,377,370
16	37·38	275,123,760	39·92	313,044,360	+ 37,920,600	16	36·32 *a*	236,897,820 *a*	37·71	197,535,700	37·75	283,884,100	− 39,362,120	+ 46,986,280
17	37·35	288,807,100	39·88	318,622,200	+ 29,725,100	17	36·67 *a*	247,310,670 *a*	37·75	213,437,400	37·75	292,468,900	− 33,873,270	+ 45,158,230
18	37·43 *a*	288,970,400 *a*	39·83 *a*	309,031,070 *a*	+ 20,060,670	18	36·88 *a*	253,558,380 *a*	37·83	215,330,940	37·67	288,946,700	− 38,221,440	+ 35,388,320
19	37·46	289,043,860	39·75	299,418,070	+ 10,374,210	19	36·97 *a*	256,235,970 *a*	37·92	218,702,000	37·63	282,024,850	− 37,533,970	+ 25,788,880
20	37·51	297,143,400	39·67	300,273,300	+ 3,129,900	20	37·13 *a*	263,825,950 *a*	38·00	216,458,700	37·75	293,130,800	− 47,367,250	+ 29,304,850
21	37·59	283,051,100	39·58	292,568,000	+ 9,516,900	21	37·17 *a*	265,324,550 *a*	38·08	228,306,740	37·83	298,684,960	− 37,017,810	+ 33,360,410
22	37·46	266,367,100	39·54	300,152,800	+ 33,785,700	22	37·23 *a*	267,572,450 *a*	38·17 *a*	228,544,050 *a*	38·08 *a*	302,696,770 *a*	− 39,028,400	+ 35,124,320
23	37·23	256,141,500	39·50	298,977,000	+ 42,835,500	23	37·31 *a*	270,569,650 *a*	38·25	228,783,700	38·13	306,708,600	− 41,785,950	+ 36,138,950
24	36·84 *a*	253,400,700 *a*	39·42	284,151,000	+ 30,750,300	24	37·31 *a*	270,569,650 *a*	38·25	237,324,200	38·29	221,729,070	− 33,245,450	+ 51,159,420
25	36·65 *a*	250,660,000 *a*	39·29 *a*	280,483,580 *a*	+ 29,823,580	25	37·28 *a*	269,445,700 *a*	38·25	228,289,600	38·38	318,939,800	− 41,156,100	+ 49,494,100
26	36·58	247,897,060	39·42	276,838,200	+ 28,941,140	26	37·12 *a*	203,451,500 *a*	38·21	227,878,600	28·58	318,459,800	− 35,572,700	+ 55,008,500
27	36·48	246,599,500	39·04	280,383,500	+ 33,784,000	27	36·97 *a*	256,235,970 *a*	38·25 *a*	231,738,080 *a*	38·67	327,795,100	− 24,497,890	+ 71,559,130
28	36·33	238,412,900	38·96	273,045,200	+ 34,632,300	28	36·93 *a*	255,035,930 *a*	38·01	218,229,900	38·58	328,773,600	− 36,806,030	+ 73,737,670
29	36·16	236,316,300	38·83	266,221,000	+ 29,904,700	29	36·97 *a*	256,235,970 *a*	38·00 *a*	204,679,200 *a*	38·50 *a*	320,579,300 *a*	− 51,556,770	+ 64,343,330
30	35·95	220,766,860	38·71	264,458,100	+ 43,691,240	30	37·17 *a*	265,324,550 *a*	38·02	191,130,970	38·50	320,579,300	− 74,193,580	+ 55,254,750
31	35·73	221,429,860	38·58 *a*	264,212,700 *a*	+ 42,782,840									
	Total.	8,424,706,440	Total.	9,034,286,120	+ 609,599,680		Total ...	7,436,028,910	Total ...	6,101,305,470	Total ...	8,451,272,800	− 1,334,723,440	+ 1,015,243,890

Note—The figures marked *a* are interpolated.

SECTION IV.

The Nawoon Embankment and the Floods.

The expediency of constructing the Nawoon Embankment.

128. When the peculiar conditions in which the Nawoon River was found during the construction of the embankment works are considered, it may well be asked, and the question has often been put, whether it was expedient—having regard to the difficulties those conditions entailed on the works themselves, and to the probable results to the plain land on the western banks through the raising of the river surface, which was a certain contingency—whether it was expedient or wise to commence or to prosecute to completion the present Nawoon Embankment? Judged only by the complete success which may now be claimed for the works, whether on financial or on engineering grounds, a decided answer in the affirmative may be given to the first part of the question. And while under anything but most extraordinary circumstances the country to the east of the embankment is fully protected and far exceeds in extent any land damaged on the western side, whatever loss may be ascribed to the works in this last respect must be admitted as qualifying circumstances to be considered as lessening their claims to what is otherwise entirely beneficial action. But these answers, taken as they are from a stand point of ultimate success after some years of what may appear to be misjudged efforts attended with serious failures, rather evade the true question, which is—postulating the statement of His Excellency the Governor General in Council of 8th October 1868, that "it would be almost criminal to disturb the existing condition of the river, only for the purpose of protecting one place at the expense of another,"—was there sufficient reason to proceed with this particular embankment, knowing, as was then known, that the Nawoon was rapidly enlarging its channel, and that the work would concur with this tendency in perpetuating floods on the western side? It can be shown that what at first sight seems the most serious objection to the work, was the most adequate reason for proceeding with it.

The original suggestion for it, and the condition of the river.

129. The first suggestion for the construction of this embankment was contained in the same letter with the statement quoted; and the necessity of carrying it out became evident when the continuous embankment from Myanoung to Henzada was definitely abandoned owing to the Thambyading erosions. The Reports submitted in 1869 and 1870 by the writer under orders from General Fraser and before quoted (1) show that the nature of the changes on the Thambyading river was fully appreciated, as the sections taken in 1865 and in 1869 demonstrated the rapid enlargement its channel was undergoing. At that time also the attack of the Irrawaddy on its western bank at the entrance to the smaller river was at its greatest power; and, though it was foreseen that there must eventually be an end to these changes when the great bend should cut across, it was also clear that they were not likely to lessen in intensity for some years, by which time it was probable that a large increase of volume would be carried by the Nawoon. The rate of increase shown by the 1865 and 1869 measurements at the Thambyading entrance, was from 3,612 to 10,906 square feet, or almost exactly triple the first measurement, implying a corresponding increase of capacity and discharge in the channel. The subsequent actual increase was from 10,906 to 18,925 square feet in the interval 1869 to 1878; which gives a somewhat lessened yearly rate of increase, that for the first five years being about 1,500 square feet and for the last ten 800 square feet per annum.

(1,)—Part III.

130. When it is considered that the mean flood velocity of the water on these cross sections ranges from 6 to 8 feet per second, giving an increase with the more moderate velocity, of from 22,000 to 66,000 cubic feet between 1865 and 1869, and from 66,000 to 110,000 cubic feet per second of water between 1869 and 1878; and that the present capacity of the Nawoon at Thapangyo is less than 150,000 cubic feet per second; the importance of these accessions of volume will be understood. And it will be seen that from this cause alone, and independently of all influence of the embankment works upon the river, the whole country on both the right and the left banks of the Nawoon was in course of being subjected to annually increasing floods which had, before the works were commenced, already reached a height sufficient to cause submersion and injury, if not total destruction of the crops on all the riverain lands. In 1871 all the cultivation was destroyed. The high flood of that year stood one or two feet over both banks. In 1872, again, when the Irrawaddy was not in high flood, Mr. Richard and the writer carefully examined both banks of the Nawoon during the flood season; and found the crops being destroyed by water passing over both the banks and overturning the feeble defences erected by the cultivators to protect their fields. The embankment, which then only reached to the 25th mile opposite Leymyethna, exercised but little influence on the flood, which, in the higher part of the river where the works were, barely rose over the banks. The revenue records for this period must contain accounts of remission of revenue on lands on both sides of the river through the natural inundations of the Nawoon, brought about by the continually increasing burden forced into the river, and which its channel was then, and still is, incapable of carrying. It is important that this disturbed state of the river since 1865 be thoroughly understood and insisted upon in considering the effects of the embankments; as it is a common error, and one frequently fallen into by Civil Officers and others, who unjustly ascribe all the evils of the inundations felt throughout this period to the embankments, to suppose that these works are the sole cause of the changes observed.

The increasing afflux through the Thambyading, the cause of the destruction of cultivation.

131. The truth is, the whole country within the range of the Nawoon floods was in as hopeless a condition as it could possibly be when the embankments commenced, and its actual state was in rapid process of deterioration through the changing regime of the river. The floods of 1871, 1875, 1876 and 1877 would have inflicted severe damage on the whole of the cultivated land had no embankments existed, and even if the Nawoon had itself suffered no changes. But with such a series of changes as are implied in its principal source of supply increasing its high-flood contribution from 22,000 to 110,000 cubic feet per second in 14 years, and its main trunk at Thapangyo enlarging both its capacity and its burden by nearly 50 per cent in the seven years 1872-1878; while, lower down, its channel for nearly the greater part from Thapangyo to Mageelaha was wholly incapable of carrying the volume of water brought to it, it is clear that even the most ordinary floods must have passed over the banks and submerged the greater part of the country now inundated, whether embankments had been constructed or not. The cross sections of the different parts of the channel showed the great probability of this result; and distinct proof of it is now available from the 1878 measurements of discharge; and from the gauge readings for other years.

The extremely critical condition of the river and the country.

132. There was no other remedy for the evil than the construction of embankments. It was practically impossible to carry out other measures for controlling or regulating the discharge of the Irrawaddy into the Nawoon. This branch of the subject has been treated at length in the last part of this Report; where the different projects for cutting across the Thambyading bend, and for closing or for preventing the further enlargement of the entrance to the Thambyading river were discussed. In the writer's opinion all those projects were

The Nawoon Embankment was the only practicable remedy.

entirely impracticable, and would have entailed enormous expenditure without any beneficial results. The acceptance of this position, which was fairly stated at the time, brought with it either the total abandonment of the lands on both sides of the Nawoon within reach of its flood waters, or the adoption of the only possible remedial measure—the construction of the Nawoon Embankment. The Local Government of Burma and the Imperial Government of India after full consideration of all the facts and opinions available implicitly accepted the policy of not attempting to interfere with the Irrawaddy and of making the best of the circumstances on the Nawoon; and it is this policy which has been consistently followed since 1868 on both rivers. The remainder of this Report contains a justification of this course in the statement of the trials to which the works have been subjected; and the results attained.

The question of double embankments for the Nawoon.

133. When it was evident that the only course offering an economical and reasonably practicable solution of the difficulties observed was the embanking of the Nawoon, it became a question whether both sides should be embanked or not. General Fraser, then Chief Engineer of the Province, contemplated a series of trunk roads to unite the principal towns. One of these roads was to follow the Nawoon line from Leymyethna to Okpho, and would have been available as an embankment on the right bank of the river from Songong to Laymyethna, or over 22½ miles of river course. The writer carefully examined the whole of this country; and caused levels to be taken both along the bank, and through the lower ground which lies between the high edge near the river channel and the base of the hills. The project was worked out; but the risks of entirely enclosing the very narrow river channel with restricted double embankments while the changes noted showed no signs of cessation were so great that, after due deliberation, the scheme was abandoned. There have been continued attempts on a minor scale since to renew such projects; and one, for a kind of Strand Road for the Town of Leymyethna, has been constructed, partly by the Civil Authorities, partly by the writer; which for a length of 4 or 5 miles crests the edge of the right bank from the Leymyethna choung southwards. But the precaution has been taken to make this sufficiently low and weak to permit it to yield before it can possibly offer a resistance to the flood, comparable to the embankment on the opposite side; so that in all high floods it suffers several breaches, which are easily repaired, and it is a great convenience to the town people as a road without being of much use as a protective work.

Estimate of the damage done through the embankment independently of other causes.

134. Nor were the interests imperilled on the right bank of sufficient extent to justify the immense expenditure which would have been entailed by constructing double embankments simultaneously throughout the length of the trunk from Songong southwards. As already explained the plains on the right bank of the Nawoon average about 4 or 5 miles in width to within a few miles north of Mageelaha, the total length in a straight line being about 32 miles. The map shows that this plain is broken up into smaller ones by at least 5 torrent streams from the Arracan Yoma, one of which debouches at Kyoukyua, close below Thapangyo; one at Leymyethna; two between that place and Ngathaingyoung, and one towards the southern limit of the plain land. The lower courses of those streams are somewhat raised above the level of the plain, though they do not stand above that of the Nawoon floods. If ever protective measures are applied to this plain land, the first measure should be to embank both sides of these streams from where they leave the hills to where they enter the river and join these embankments on to an embankment on the right bank of the Nawoon. This will break up the plain into five distinct areas lying between the river and the hills; into which a small portion of the hill water will drain, and which will receive their own rainfall. As a rule the whole of this plain land lies at a level from 8 to 12 or more feet below that of the edge of the bank near the river, and thus at flood-time is still more submerged. The elevated edge of the bank on the Nawoon is generally very

narrow; rarely reaching a quarter of a mile in width; and often the slope towards the interior commences at once. There is thus very little land available for cultivation along the rivers edge; and, actually, the quantity ever in cultivation there was small. None of the interior low land could be cultivated; but there is a margin of land at the base of the hills where the ground commences to rise which has long been under cultivation. The cross section at the bottom of Plate VII shows the arrangement of the country due west of Ngathaingyoung. First there is the elevated edge, next the low land, then the line crosses one of the hill streams before referred to and rises to again fall, and lastly the hilly ground is reached. Here the levels show that the ground rises 8 feet in half a mile. The facts narrated prove that all the cultivation on the narrow strip of land on the rivers edge, and all the land at the same level or a little higher up to the flood level of 1871 at the base of the hills was being thrown out of cultivation through the elevation of the surface of the Nawoon, occasioned by the continually increasing influx through the Thambyading river. It is a fact which the most careful enquiry will verify and place beyond contestation that the whole of this land has been thrown out of cultivation independently of the effect of the embankments. But there remains a narrow strip of this land at the base of the hills which has certainly suffered through the construction of the embankments. It will shortly be shown that there has been a distinct rise in the Nawoon river surface ascribable to these works. The amount of this is probably 4 or 5 feet at Mageelaha to the extreme south of the plain land; and, though this cannot be exactly determined, it is probably nothing at Thapangyo, near the northern point. Assuming the base of the hills to have the same transverse slope throughout, the strip of land damaged by the floods will be 1,500 feet wide at the lower end and nothing at the upper; or in all, taking it to be 50 miles long, it is less than 5,000 acres in area, of which a portion only was cultivated. This, and this only, is the amount of damage done by the works (1).

General ignorance regarding the extraordinary changes on the Nawoon.

135. It has been necessary to go into this matter with some detail as considerable misapprehension appears to exist amongst residents near the Bassein River as to the action of the embankments. There has been, apparently, little or no knowledge of the extraordinary and abnormal development of the upper Nawoon during the last 15 years; and thus it has not been possible to discriminate between the two sets of causes and their effects; and, not unnaturally, all the evil results observable on that river have been ascribed to the embankments, the extension of which has come prominently into notice. Indeed, occasionally, the results due to the excessive floods in the heavy rainfall and flood years of 1875, 1876, and 1877 have been put down to the embankments, the extent of whose ill effect is wholly comprised within the limits stated. It is hoped that even this will disappear in the same manner as recorded for the Rhine works, and those of the Garonne, where the increased velocity and the concentrated force generated by the flow of the water after the first elevation of the river surface speedily caused an excavation of the bed of the river, which was followed by a reduction of the flood surface to almost its former level. There is reason to believe that this process is already in operation on the Nawoon. When it is complete, the five areas on the right bank can be taken up; and, if it can be shown that their reclamation will be profitable, measures may be carried out to protect and drain them.

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(1).—Extract from Revenue Report of the Deputy Commissioner Bassein for the year 1878-79.

"But if the land has afforded protection on the eastern, it has been the reverse on the western side of the river, for the water which formerly inundated these circles has been thrown on the low lands of the opposite circles on the western bank and partially destroyed or injured cultivation. In 1873-74 the cultivated area of these 10 western circles was acres 24,144 and the average annual increase in the 5 previous years was acres 746. In the present year the cultivated area of these 10 circles is acres 24,021 a decrease of acres 123 as compared with 1873-74 with the total loss of the usual annual increase. The reason of the decrease in 5 years being so small is that where the low lying lands have been abandoned, the people have managed to cultivate in higher lying lands which before the erection of the bund were neglected, but which still in time, and the usual annual increase would eventually have been brought under cultivation."

136. On the left bank of the Nawoon the action of the embankments is now entirely beneficial. There has been an interval in their history, during the floods of 1876 and 1877, when it seemed as if their success was questionable; but it will now take even greater floods than that of 1877 to again imperil them as a system, though isolated failures and breaches may always occur through weakness in the ground or through neglect of the works. A brief recapitulation of the facts and figures before given with a few further statements will make this evident. The physical conditions under which the works were commenced were sufficiently onerous; and it required a thorough reliance on the regularity in the operation of the laws of nature in their manifestation on rivers, as well as a prudential resolution to prolong the works only so far as it was manifest they could be safely extended, to venture on the task while the Thambyading river was opening out into the Nawoon to such an extent as to cause competent observers to seriously believe that the Irrawaddy main channel was in course of diversion to the westward :—

Former prospects of the Thambyading Bend.

137. In the first place it was known that these immense bends are really a normal feature on all great rivers flowing through alluvial plains, and continually recur. On the Ganges they are said to take 80 years from their incipient formation until their final cut-off. In 1868 the Thambyading bend had sufficiently developed to the usual form to suggest to Mr. Bennett and to General Oliphant the cutting across of the neck; and it was apparent that it was only a question of time when this should take place. In the meantime the steady progress of the point of the bend westward caused serious disquietment, accompanied as it was by the rapid enlargement of the Thambyading river; and, while holding the belief that there were no real grounds for the expectation that the Irrawaddy is, under present circumstances, likely to be diverted in the direction of the Nawoon, it became a matter for enquiry what would be the probable results on the country of such a diversion, as any intermediate stage of enlargement of the open channels must of course be comprised within such results.

Examination of the probable results of a diversion of the Irrawaddy into the Nawoon.

138. On comparing the plans and profiles of the Irrawaddy and Nawoon rivers, we find, taking Thambyading as a starting point, that the 1871 flood surface, which is throughout almost parallel to the elevated land on the rivers edge, stood at the following heights at the places whose distances are given :—

Table 39.

IRRAWADDY.					NAWOON.				
Station.	Distance.			1871 Flood height.	Station.	Distance.			1871 Flood height.
	By River.	By Embankment.	Straight line.			By River.	By Embankment.	Straight line.	
Thambyading ...	0	0	0	47·00 (?)	Thambyading ...	0	0	0	47·00 (?)
Nawoon ...	5	5	4¼	44·76	Myogwin ...	8	11½	8	41·44
Henzada ...	16¼	13½	13	42·48	Leymyethna ...	30½	25½	21	32·16
Zaloon ...	33½	30½	25	35·47	Zimbyogong ...	43	35½	26	27·86
Donabyo ...	62	52	40	25·50 (?)	Ngathaingyoung...	64½	47	34	22·29
Setkaw ...	76	70	52	18·00 (?)	Mageelaha ...	87	60	45	16·39
...	...	...	...	...	Zeebingwin ...	98	70½	52	12·96

This table is drawn up on the assumption that the point from which the straight distances are measured is that where the entrance was in 1871; and the estima-

ted flood height of that date is taken, although a similar flood now would give a different height, as somewhat less than half a mile of the bank has been cut away since 1871.

Comparison of the courses of the two rivers.

139. The first distinction observable is that the Irrawaddy has a shorter and straighter course than the Nawoon, as on a straight line of 52 miles the former has a channel only 76 miles long, while the latter is 98 miles long. It is noticeable, however, that the embankment length is the same in both cases; the Nawoon one having been measured from the junction of the two rivers. The three bends on the Nawoon account for the increase of length in its course; and a first consequence of the diversion of the Irrawaddy would be to cut across these bends, and shorten the channel by over 20 miles to nearly the same distance as it has at present to Setkaw.

The Nawoon is more inclining than the Irrawaddy.

The banks of the Nawoon are lower than those of the Irrawaddy.

140. A second distinction is more important. As all the distances of the places given on the Irrawaddy and on the Nawoon do not coincide, an immediate comparison cannot be made from them; but it is at once obvious that all the Nawoon stations are at a relatively lower height than the Irrawaddy ones. The greatest difference is probably at Zimbyogong, the 35th embankment mile, where the Irrawaddy station is about $6\frac{3}{4}$ feet higher than the corresponding point at the same distance on the Nawoon in a straight line from Thambyading. At Zeebingwin 52 miles distant in a straight line from the same place, the 1871 flood level and the general level of the country on the bank of the Nawoon is about 5 feet lower than at Setkaw, which is at almost the same distance on the Irrawaddy both by embankment and in a straight line. The ultimate result of the Irrawaddy being diverted to follow the course of the Nawoon would be that the high flood level and all the country near the banks would be raised from 5 to 7 feet over a portion of its length.

The construction of embankments improves the course of a river.

141. These figures contain nothing formidable, as the process indicated could be achieved without any serious derangement of the existing condition of the country, provided only it were accomplished by gradual stages. The much smaller changes due to the enlargement of the Thambyading must necessarily entail a lesser degree of derangement; and the extreme rapidity with which the whole length of the Thambyading itself and the succeeding portions of the river have accommodated themselves to the altered rate of supply at the entrance is a proof that the same result must speedily ensue throughout the whole length of the trunk, if the increased flood discharge can be forced down it. The construction of the embankment promotes this tendency, as the super-elevation of surface caused by the works combines with the increased volume of water in the river, and must cause an increased scour of the entire channel. It was a full reliance on the efficacy of these processes, which were in continual operation under the eyes of those responsible for the prosecution of the embankments, which gave them confidence to undertake them in as severe a set of surrounding conditions as ever such works were executed in.

Gradual extension of the works.

142. The works were designed in lengths of about 25 miles each; but in actual practice shorter lengths were added after an interval when the preceding part was subjected to a year's flood. The first instalment, in 1869, was only 4 miles long; and the second one in 1871-72 was considerably longer, being $21\frac{1}{2}$ miles in length; but that of 1872-73 was only 14 miles; that of 1873-74 about $7\frac{1}{2}$ miles; that of 1874-75 only 6 miles, bringing it to the 53rd mile before the occurrence of the 1875 flood.

Changes in design and condition in 1875.

143. As first designed in 1869 the older pattern of embankment was followed. The top was 5 feet in width, and stood 5 feet above the highest flood mark of 1868; with an outer slope of $2\frac{1}{2}$ to 1, and an inner slope of 2 to 1. The designs were afterwards revised, giving a top width of 14 feet, raised 3 feet

above the 1871 highest flood, with slopes as before. It was found that a free-board of 3 feet was sufficient in practice when well authenticated high flood marks existed; provided there was sufficient strength in the work to withstand the pressure, and this was secured by the increased width; which allowed, in ordinary circumstances, the embankment to be useful as a road; and, in high flood, permitted further small embankments to be hurriedly raised upon it in emergencies. The work was originally raised to an excess height of $\frac{1}{6}$th over that actually required, in order to permit it to settle down to the desired height. It was found that this was insufficient; as, either through the peculiar nature of the earth, which is generally a strong loamy mixture of clay and silicious sand, or through the water standing against it for some months during each flood season and thus causing unusual settlement, an excess height had to be given of $\frac{1}{4}$th the required height of the work. This is now invariably given. But in 1875 when the flood came down the insufficient excess given had, through a long course of settlement, brought the crest of the work unduly low in several places. On the 16th, 17th, 18th, 21st, 22nd, 23rd, 28th and 36th miles the top of the work stood in 1875 only between one and two feet above the 1871 flood marks.

144. The floods of 1872, 1873 and 1874 were of an ordinary character; and their highest points marked from 36 to 37 feet at Henzada on the gauge. No particular result was apparent from the extensions of the embankment in those years. The writer was absent during the 1873 and 1874 floods; but any noteworthy elevation of the surface of the Nawoon would have been placed on record. In 1875 such an elevation took place. Two waves came down, one in July, one in August. That of July marked the same as the 1871 one at Myogwin, the 12th mile of the embankment. At Leymyethna, the 25$\frac{1}{2}$th mile, it rose to 0·7 feet higher; at Zeebyogong the 35$\frac{1}{2}$ to 1·35 feet; and at Ngathaingyoung 6 miles from the end of the work it was again equal to the 1871 flood. In the August wave again the elevation was still greater. On the 19th August the river at the Nawoon entrance marked one foot above the level of 1871. At the 12th mile it was 1·76 feet; at the 25$\frac{1}{2}$th mile 1·75 feet; at the 35$\frac{1}{2}$ mile 2·3 feet; and on the 21st August at Ngathaingyoung the 47th mile it was 2 feet above the flood of 1871. How much of this excess was due to the changes on the Thambyading river, how much to differences in rainfall, and how much to the embankment must now be investigated.

The 1875 floods.

145. The changes on the Thambyading river between 1871 and 1875 were twofold. The Irrawaddy had encroached about $\frac{1}{4}$th of a mile on the bank at the entrance, and its main channel was that much nearer to Myogwin. The entrance itself had considerably enlarged, and the volume of the united Nawoon must have increased by a still greater amount than that shown by the 1872 and 1875 measurements. This alone must, as before explained, have certainly raised the surface of the Nawoon by a greater amount in its trunk than at the entrance. The elevation of the second wave was here one foot above that of 1871. It seems not unreasonable, considering the position of Myogwin at a part of the river when it is wholly unconfined and unrestricted, and giving weight to the two changes in the Thambyading just mentioned, to suppose that the excess rise of 0·76 feet at Myogwin over that at the entrance was principally due to these changes. If so, we have a starting point for comparison. The excess at Leymyethna, 23 miles by river channel, 14 by embankment, lower down the Nawoon, was almost exactly the same as at Myogwin, or 1·75 feet against 1·76 feet. These figures are conclusive that very little of the elevation as far south as Leymyethna was in 1875 due to the embankments as they then stood. But there is an excess of 0·55 feet at Zeebyogong, and one of 0·25 feet at Ngathaingyoung above the Leymyethna elevation requiring explanation.

Analysis of flood heights.

146. The rainfall records may throw some light upon this. In Part II of this Report most of the available information under this head has been

gathered together, and, analysed with regard to the Irrawaddy generally. For present purposes only the portions relating to the Nawoon watershed will be referred to. It happens that no record has been kept for any of the years under consideration at any station within the area of these watersheds; and we must therefore depend on the nearest ones to it. Bassein lies to the south-east of the area; but as the rain bearing winds come mostly from the south-west, it lies slightly out of the path of the supply. Sandoway on the sea-coast is also too far to the westward; and receives the full force of the monsoon, while the Nawoon watershed must get it when partly denuded of its moisture. Henzada and Myanoung are to the east and north of the areas. Rangoon is similarly situated to Bassein but further away and its indications will serve to check the others. The average falls of these stations and the differences from those for the years 1871 and 1875 are given in Table 40 below.

Rainfall on the Nawoon watershed in 1875, compared with average fall and that of 1871.

Table 40.

	Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Average Rainfall.	Bassein ...	0·25	0·00	0·14	1·02	7·53	16·22	26·28	21·81	14·50	7·27	2·56	0·03	97·61
	Henzada ...	0·00	0·00	0·00	0·56	6·13	15·74	19·39	16·96	11·02	4·67	2·99	0·00	76·33
	Myanoung ...	0·00	0·00	0·00	1·70	3·70	9·30	9·25	11·05	9·30	5·70	1·70	0·20	52·00
	Rangoon ...	0·06	0·06	0·08	1·69	12·27	19·82	21·67	18·56	15·61	9·06	2·83	0·00	101·71
	Sandoway ...	0·07	0·09	0·20	0·78	15·04	53·07	59·95	49·68	24·91	12·23	2·52	0·09	218·58
Differences for 1871.	Bassein ...	−0·25	0·00	−0·14	−0·72	+3·77	+9·78	−8·98	−7·41	−0·50	+0·83	−1·86	+0·17	−4·21
	Henzada ...	−0·11	0·00	0·00	−0·56	+4·17	+10·26	−3·09	−2·76	+1·98	+2·33	−2·29	0·00	+9·98
	Myanoung ...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Rangoon ...	−0·06	−0·06	−0·42	−1·69	+14·73	+12·58	+5·58	+8·74	+3·59	+0·54	−2·83	0·00	+41·69
	Sandoway ...	−0·07	−1·09	+1·00	−0·78	+13·06	+11·53	+0·35	−2·13	−6·11	−2·33	−2·52	−0·09	+11·32
Differences for 1875.	Bassein ...	+1·67	0·00	−0·14	+0·90	+2·75	+8·05	−2·33	−6·53	+7·59	+3·40	−1·54	−0·03	+13·79
	Henzada ...	−0·11	0·00	0·00	+3·74	+4·13	+0·40	+13·45	+5·70	+1·33	+0·66	−0·92	0·00	+25·11
	Myanoung ...	+0·01	0·00	0·00	+4·80	+2·90	−2·70	+3·85	−0·15	−6·10	+1·50	−0·03	−0·20	+4·60
	Rangoon ...	−0·06	−0·06	−0·08	+3·21	+4·63	−4·32	−4·07	−9·06	−7·71	−5·96	+1·07	0·00	−22·41
	Sandoway ...	+0·43	−0·09	0·00	+1·72	−5·24	−6·17	+21·85	−14·13	+10·69	+5·07	−2·22	−0·09	+11·82

These figures show that in 1871 there was a general excess in June, while the same month in 1875 appears for most of the stations about the average. The rainfall for this month has little influence on the subsequent floods ; as, though much of it may be employed in saturating the ground, the remainder has generally drained away by July and August. The Myanoung record was not kept in 1871, so that no comparison can be made there. For the other stations it appears that in July 1875 Bassein received 6·65 inches more than in July 1871, Henzada 10·36 inches, and Sandoway 21·5 inches. Rangoon, which is far to the eastward received 9 inches less. The first three stations, however, from their situation, prove that the monsoon current supplying the Nawoon was much more heavily laden in July 1875 than in July 1871, although none of those figures can be taken to accurately represent the excess that fell on the watershed. In August the differences are less at all the places.

Excess fall in July and August 1875.

147. If for the sake of fixing the notions, we take the Bassein fall, which is the nearest to the current of rainfall supply, we have about 7 inches more rain from the watersheds added to the Nawoon river during July 1875 than in July 1871. This means, for every inch of fall, nearly 64,000 tons to the square mile ; and as there are about 1750 square miles of watershed draining into the channel where it was embanked in 1875, the total added in excess was nearly 800 million tons. But the watershed has been considered divided into two portions, that to the north of the junction of the Nawoon entrances at Songong, containing over 800 square miles, and consisting of the Okpho and Mamya torrents and the Myanoung plain ; and of that to the south containing some 680 square miles of torrent basins in the Arracan Hills, and of 220 of plain land on the west of the river channel. The greater part of the rainfall upon the first portion would only be delivered slowly to the Nawoon after being stored up, together with the flood spill from the Irrawaddy, over the Myanoung Plain. The excess in this part would doubtless contribute to increase the elevation of the river surface at Myogwin in July and in August, but could have little effect in producing the excess elevation below Leymyethna. That which fell on the remaining 900 square miles draining into the channel to the south of Myogwin had more importance, as it would be delivered sooner to the channel. The quantity added to this watershed would be over 400,000,000 tons ; which, distributed over 31 days, would give 13,000,000 tons daily in excess above the burden of the Nawoon in 1871 ; but, as the daily rainfall tables given in Part II show, this amount came down mostly in heavy showers in the latter half of July, which were followed by excessive falls in August, particularly at Henzada, where 6·52 inches fell on the 10th and 11th and 2½ before the 17th, and at Bassein, where 7 inches fell between the 10th and 17th of the month. If, as is most probable, similar or heavier falls occurred simultaneously on the Aracan Hills directly opposite, about 500 million tons were added to the Nawoon between Myogwin and Mageelaha from the lower local watershed in one week shortly before the very high rise from the 19th to the 21st August.

Excess elevation of surface due to large rainfall.

148. Some portion of the super-elevation of surface in 1875 must have been produced by this great accession of rainfall ; but as, at this stage of the river, the whole space from the river channel to the hills is inundated, the river practically consists of two channels ; one the regular narrow channel of 500 or 600 feet wide with swiftly flowing water, the other from four to five miles wide, the water in which flows with a marked velocity, opposing a considerable current to the passage of ascending boats. The excess rainfall would be distributed over the whole of these areas, and, large as the excess is in amount, could, when distributed over the whole month, only raise the surface in a slight degree. It is more than probable that the extension of the embankment from the 25th to the 53rd miles in the interval between 1871 and 1875 had an appreciable effect in raising the surface ; and, though no figures can be used to distinguish the several results, the two causes of local heavy rainfall and res-

triction of the flood spread area through the embankments combined to produce the excess noted between Leymyethna and Mageelaha. A large out-flow of nearly 10 miles in extent was left open for the flood to escape freely on the left bank between the 53rd mile and 63rd at Payagyee in 1875; and this lessened in a great measure the acute effects of the flood of that year. In the early part of 1876 the prolongation of the embankments to the 70th mile closed this exit; and for the first time, through their approach to the hilly ground which comes down to the river on the right bank at Payagyee, made them act in raising the river surface.

Critical condition and preservation of works during the flood.

149. It has been noted that the continual settlement of the work since its first construction had lowered the crest of the embankments on several miles to within one or two feet above the 1871 flood mark, where it should have been at least 3 feet above it. The rise of the river to from 1·75 to 2·3 feet above the 1871 flood mark applied a severe test to the stability of the embankments; which, unfortunately, had not been brought up to their proper height when the flood came. The great rise of the July wave in 1875 however, gave warning, and every effort was made to throw up on the lower parts a small dam on the embankment crest. Mr. Hallett, Executive Engineer, had temporary charge of the sub-division comprising the Nawoon embankment, and it was to his exertions, ably seconded by the Civil Officer, Captain Cresswell, that the safety of the works was due. The villagers along the line, who saw the peril, and who appreciated the work, turned out in large numbers and lent a ready and cheerful aid. The embankment stood all the tests, without a single breach, though in many places it showed signs of weakness. The successful result of this test applied in such a want of preparedness and with such an exceptional and sudden rise of the river proved that the general design of the works was suitable, if they were kept in proper order; while it also proved that the margin of safety had in some cases, through economical grounds, been run too close to the actual requirements. A new set of estimates was accordingly prepared under the authority of the Local Government, and sanction was granted by the Imperial Government to raising all the embankments to a uniform height of 3 feet above the highest marks of the 1875 flood; the same dimension of 14 feet top width, and slopes of 2½ to 1 and 2 to 1 being assigned for the new work.

Estimate for raising and strengthening the works.

150. The first portion of 25½ miles called the Leymyethna section had cost up to the year 1874-75, Rs. 2,57,863. The estimate for raising and strengthening this amounted to Rs. 61,084. The second portion to the end of 53rd mile was called the Ngathaingyoung section. Its cost, to the end of the year 1874-75, was Rs. 1,96,443. A further sum of Rs. 68,018 was required to carry out the additional work rendered necessary by the 1875 flood.

The Taboo Section of the Nawoon Embankment.

151. Another extension of about 26 miles of the Nawoon embankment had been designed and sanctioned; and, after the flood of 1875 went down, orders were received to proceed with this in addition to carrying out the raising and strengthening of the older works. The design of the new portion of the embankment, which was called the Taboo Section, was originally for a height of 3 feet above the 1871 flood, with the uniform shape and dimensions. The estimated cost of this work was 103,534 Rs. The flood of 1875 demonstrated the necessity of raising and strengthening the new section in the same manner as for the older ones; and a revised estimate was prepared. This additional work required to the Taboo Section brought its estimated cost to Rs. 1,23,513. In all, the three sections of the Nawoon embankment which were ordered to be proceeded with in 1875-76 required an expenditure of at least Rs. 2,52,615 to raise them three feet above the 1875 flood level and give them the proper strength of cross section. Of this sum only Rs. 1,00,000 was originally made available in 1875-76, for the Taboo embankment, and this was afterwards

reduced to 77,800 Rs. to provide money for raising the older works on the Irrawaddy, while another portion was diverted to the upper Nawoon line. The total expenditure on the three Nawoon Sections reached, however, Rs. 84,773 by the end of the financial year on 31st March 1876, of which 48,102 Rs. were utilized in roughly throwing up about 20 miles of the Taboo embankment.

Insufficient money provided for the works in 1876.

152. The orders of the Local Government in September 1875 were to try and complete this work; but they were subsequently modified as the necessity became apparent for placing all the other embankments in good condition. In the financial year 1876-77 only 15,000 Rs. were given for the Taboo Section, while Rs. 38,100 were provided for raising and strengthening the whole Henzada embankment. Of this Rs. 7,000 were spent up to the end of July on the Irrawaddy side, and 24,200 Rs. on the Leymyethna and Ngathaingyoung Sections. The extreme urgency of the raising work caused a deviation from the usual practice of deferring the spending of each year's grant till the dry season of the year and the double grant for the years 1875-76 and 1876-77 was mostly expended in the dry season 1875-76, and every effort was made to utilize the money in making the weaker parts of the embankment safe before the first flood. The same was done as far as possible with the Taboo Section; as, against Rs. 15,000 allotted, Rs. 20,000 were expended before the 1876 flood came, the excess being deviated from the Irrawaddy embankments. Thus the total spent up to July 1876 on the Nawoon embankment was Rs. 1,28,973 against Rs. 2,52,615 required. This left the works in a condition far short of the requirements deemed necessary for safety; for the 7 miles of the Taboo section still untouched are of a very light and inexpensive character.

The 1876 flood.

153. It is evident that the utmost that the means at disposal allowed had been done to make the works safe; and, as was most desirable, the older works, which had already exercised protective action and sheltered large numbers of newly settled agriculturalists, received the preference. When the flood of 1876, which was a purely local one, and which did not extend beyond the Nawoon, came down, the two upper sections stood the test while the newly thrown up and unconsolidated work of the Taboo Section was breached in three places. Very little harm was done either to cultivation, which had barely extended into the new region, or to the embankments, as Rs. 4,016 covered the cost of the extra work of repairing them. But as the 1876 was a preliminary monition of the greater flood of 1877 it is important to examine the conditions attending it.

154. The heights of the 1871 and 1876 floods as before given are :—

Table 41.

Heights of the flood on the Nawoon.

Name of Place.	Mile by River.	1871 Flood + M S L.	1875 Flood + M. S. L.	Difference.
Henzada on Irrawaddy ...	...	42·48	41·30	−1·18
Myogwin on Nawoon ...	8	41·44	41·25	−0·19
Leymyethna	31	32·16	33·26	+0·10
Zeebyogong	43	27·86	29·27	1·41
Ngathaingyoung	65	22·29	24·79	2·50
Mageelaha	87	16·39	19·97	3·58
Zeebingwin	98	12·96	14·40	1·44

The characteristics of the flood wave at the different stations will be dwelt upon after the later floods have been described. The principal point to be noted here is that, except at Mageelaha, the 1876 flood did not rise over 3 feet above the

height of the 1871 flood marks. Here the excess was 0·58 feet, and between two and three miles higher up the embankment, where the highest rise of all was, the excess was not over 0·85 feet above the freeboard provided in the original estimate ; and was less than the height the embankment would have been had all the raising work provided after the flood of 1875 been carried out. The flood of 1875 had clearly proved that the section of the embankment was sufficiently strong to meet a flood rising up to and over its crests, if due precaution were taken to raise a slight dam on the top. This was done ; but the want of strength in the main structure caused the whole to yield to the unexpected pressure.

The rainfall for 1876 on the Nawoon watershed.

155. The causes of this rise, which the figures prove was purely local, were undoubtedly the restricting effect of the embankments, and very heavy rainfall on the Nawoon watershed. If we could ascertain by a comparison with the rainfalls and floods of previous years how much of this was due to the rainfall the remainder would clearly be the effect of the embankment restriction. Taking the differences of rainfall from the average as given in Part II for the stations before mentioned and adding Myanoung we have :—

Table 42.

Differences of rainfall from average for the year 1876.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Bassein ...	-0·25	0·00	-0·14	+1·15	+1·94	-3·15	+8·88	-4·31	+2·19	+0·25	+0·04	-0·03	+6·57
Henzada ...	-0·11	0·00	0·00	-0·29	+3·26	-0·45	+2·03	-6·00	-1·11	+0·11	+2·16	0·00	-0·40
Myanoung...	0·00	0·00	0·00	-1·70	-1·10	-4·30	+0·55	-4·15	+7·20	-1·20	-0·60	-0·20	-5·60
Rangoon ...	-0·06	-0·06	-0·08	-0·28	+5·26	-7·10	+4·28	-1·98	-0·91	-5·56	+2·79	0·00	-3·70
Sandoway...	-0·07	-0·09	-0·20	-0·78	-8·82	-26·83	+5·97	-25·19	-6·04	-5·07	+2·01	-0·07	-65·18

The year 1876 had one of the smallest rainfalls upon record for Indian stations generally, but July appears to have been an exception to the rule for the year ; and the circumscribed locality in the neighbourhood of Bassein received unusually heavy showers of rain, which must have spread over the whole Nawoon watershed. Compared with the falls in 1871 and 1875 the excess was still more marked ; as, in the first year, only 17·30 inches fell in July ; while 23·95 are recorded in 1875, and 35·16 inches in 1876 for the same month at Bassein. The differences in excess are 6·65 inches in 1875, and 17·86 inches in 1876 over 1871, so that if in both the later years the Irrawaddy had stood at the same height at the Nawoon entrance there must have been a raising of the surface in the Nawoon owing to the rainfall alone. As a matter of fact, the Irrawaddy was one foot higher in 1875 and over one foot lower in 1876 than in 1871. It is impossible to state with accuracy how the rainfall discharge was distributed in its time of arriving at the river ; but it is to be mentioned that two heavy showers, one of 4·80 inches on the 8th July, and one of 4·95 inches on the 15th are marked at Bassein. The two divisions of the watershed would act unequally, the Myanoung one of 850 square miles would not contribute its quota to the Nawoon till August, while the watershed of 900 square miles entering south of Thapangyo would send its portion into the channel and side plains much more rapidly.

Passage of the flood waves.

156. The river, which marked 33·95 feet on the gauge at Ngathaingyoung on the 8th July, marked 36·17 feet on the 15th, and rose to its highest point for the year there on the 29th, when it marked 40 feet. It now stood nearly 3 feet over the banks in this part and the spill rapidly filled the low plains to the right of the river. The gauge at Mageelaha marked 39·79 feet on the 31st July; but it is curious to find that while the August rainfall was slightly below the average, and the river fell to 38·42 feet at Ngathaingyoung by the 12th August to rise again to 39·50 on the 2nd to the 4th September, the Mageelaha gauge shows a fall to 38·42 on the 28th August, with a further highest rise for the year to 40·00 feet on the 3rd September. The gauges at the lower stations of Zeebingwin and Taboo marked 40·00 on the 4th September. The only explanations of the oscillations can be the heavy rainfall which took place at the end of August, when 2·63 inches were recorded at Bassein on the 31st August, with other heavy showers on other days.

Effect of the Embankment works.

157. The 17·86 inches of rainfall in July 1876 in excess of that in July 1871 imply on the whole Nawoon watershed of 1750 miles a surplus of 2,000,000,000 tons, which would be mostly stored up in July in the plains on the right of the river to issue in the restricted channel at Mageelaha and would keep it full to the brim through August, so that the subsequent heavy showers on the lower watershed would be readily felt. The embankments therefore tend to re-act upon the local rainfall drainage, as well as on the regular discharge of the river; and by far the greater part of the elevation of the surface must be ascribed to them, although the unusual rainfall brought this tendency into prominent relief.

The 1877 flood.

158. The flood of 1877 showed this still more markedly. On this occasion all the three causes which can induce to elevate the surface of the Nawoon river were in operation:—an immense Irrawaddy flood, an excessive and unprecedented local rainfall, and the restricting action of the embankment works. The latter did not operate efficiently, so that the full extent of their action was not developed. The reasons for this were, as in 1876, purely financial ones, as will now be shown.

The financial allotments and the working seasons.

159. The breaches in the new Taboo Section in 1876 were repaired very soon after they occurred; and, owing to the urgent representations made of the necessity of applying further funds to strengthen the works, a further grant of Rs. 15,000 was made on the 15th October 1876; bringing the total allotment for the year to Rs. 30,000, of which Rs. 29,943 were spent by December 1876. The working season commences in this month, and labourers from Upper Burma came down in October and November in each year in search of employment, to return there by the April or May following. If their services are to be availed of they must be engaged in November or December at latest; otherwise they journey on southwards to find occupation in the seaports. The settled population is very scarce in the neighbourhood of the embankments when they are first constructed; and, afterwards, well-to-do farmers and brokers do not care to work as common coolies when work is required to the embankments. It is, then, to the stream of Upper Burma labourers that we must look to carry out any large works and they must be secured by December or the seasons work is lost.

Representation of the urgency of further conditions to the works.

160. These facts were represented to the Local Government in Rangoon; and it was pointed out in a memo by Mr. Wallnutt, the officer in immediate charge, forwarded by the writer on the 20th November 1876, that coolies were then collected in the neighbourhood of the works ready to go on with the raising. The letter stated:—"The undersigned has the honor to forward a copy of Mr. Wallnutt's No. 206, dated 16th November 1876, and to inquire if

any work may be done in anticipation of next years allotment provided the contractors agree to wait for payment till 1st April 1877. The coolies are collecting and will go away soon if there is no prospect of work." Mr. Wallnutt's memo pointed out that on both the Ngathaingyoung and Taboo Sections large number of coolies were waiting for work, having been led to settle there in anticipation of funds being forth-coming. They speedily used up all the money available; and the works were staked out to the required heights and strength so that if only the money had been granted in time all the requisite raising &c., could have been easily done.

Reply of the Local Government.

161. In answer to the writer's representations the following letter was received regarding the Taboo Embankment, No. 4915-66 A., Rangoon 28th November 1876; "In reply to your letter and its accompaniments from Mr. Wallnutt enquiring whether work may be done on the Taboo Section in anticipation of next years allotment, I am directed by the Chief Engineer to state that under the limitation recently put on the grant for Irrigation Works for 1877-78 there is no possibility of any further extension of the embankment being undertaken this year. The allotment for the works during the current year should not be exceeded and as the Chief Engineer objects to forestall any portion of next years Budget, the coolies who have been collected for work must be allowed to depart."

Other representations and application to the Supreme Government.

162. In reply to another representation regarding the dangerous state of the Ngathaingyoung Section, a copy of the following letter to the Government of India was received. "To the Secretary to the Government of India, No. 4840-66 A., dated Rangoon 21st November 1876. Sir. With reference to Public Works Department No. 292 I., dated 8th July 1876, communicating sanction to estimates aggregating Rupees 3,04,640 for raising and strengthening the Irrawaddy Embankments, I am directed to point out that the allotment for raising the Henzada Embankment is quite inadequate for the proper progress of the work as it would leave the embankment in a very insecure state for the next year's floods. The statement in the margin shows that a balance of Rs. 74,471 will be required to complete the work. The original grant stood at Rs. 60,000 but was subsequently reduced to Rupees 38,100..... .....2. Mr. Gordon, the Executive Engineer, represents that portions of the Henzada Embankment near Ngathaingyoung are dangerously low and run a risk of being topped or breached by next year's floods, if measures are not at once taken for procuring labourers. After the month of March workpeople are difficult to collect and the work required to make the embankment secure may not be done. 3. Under these circumstances I am to ask whether an additional appropriation of Rs. 50,000 could be given during the current year for this work by by reducing the next years' allotment by a corresponding sum. 4. Early orders are requested on this reference:"

Delay in obtaining money.

163. Some delay was experienced in obtaining orders on this matter. The reply of the Government of India is dated 18th January 1877, and communicated sanction to a sum of Rs. 40,650 being spent on the urgent work. The order only reached Henzada on the 2nd February 1877, when it was found that the whole of the coolies had gone away from the works, and there was every prospect of great difficulty in obtaining any labour. This was represented by the writer on the 6th February, and it was decided to utilize the money as far as possible, and to divert the remainder to the other works. It was found that only about Rs. 12,600 could be so utilized before the end of March, and owing to the same cause, want of labour, only Rs. 10,000 in addition to this could be spent on the Ngathaingyoung Section before the flood of August 1877. The works still required about Rs. 30,000 to raise it 3 feet above the 1875 flood, and give it proportional strength. The most dangerous and heaviest parts were made secure, and all that could be done by a careful distribution of the money was done.

Unfinished and dangerous condition of the works in 1877.

164. The Taboo Embankment remained in much the same state when the August flood came in 1877 as at the close of the previous financialyear. From want of labour only Rs. 6,000 were spent from 1st April to the end of July; and though much had been done to render certain parts which seemed most threatened secure, the work as a whole was far from being in proper condition. It was neither to the full height required, nor to the full strength. A further estimate, amounting to Rs. 64,000 for additional raising and strengthening had been sent in by the writer, as soon as possible after the 1876 flood, with a report showing the necessity of providing for the extra rise caused in the lower part of the channel by the restrictive action of the embankment as well as for that caused by extraordinary local rainfall; but the Government of India considered that the whole subject had acquired such an importance from the continually varying conditions in which the Irrawaddy and the Nawoon were found, that until those conditions were determined and thoroughly understood no new estimate relating to these works should be sanctioned. A sum of Rs. 45,000 had, however, been appropriated to the work for the year 1877-78, and the writer utilized this as far as he could in carrying out the raising required. Unfortunately, little could be done before the flood came down.

Height of the 1877 flood.

165. The heights attained by the 1877 flood on the Irrawaddy and on the Nawoon are given in Table 43 below, with these differences from the 1871 flood for comparison.

Table 43.

IRRAWADDY.					NAWOON.				
Station.	Mile from Saiktha.	1871 Flood.	1877 Flood.	Differences.	Station.	Mile from Thambyadeing.	1871 Flood.	1877 Flood.	Differences.
Saiktha ...	0	...	79·74	...	Nawoon ...	...	44·76	46·10	1·34
Myanoung ...	15	70·15	71·87	1·72	Myogwin ...	8	41·44	44·26	2·82
Shwegyeen ...	35	60·50	62·09	1·59	Leymyethna ...	31	32·16	35·41	3·25
Nawoon ...	73	44·76	46·10	1·34	Zimbyogong ...	43	27·86	31·86	4·00
Henzada ...	84	42·48	43·78	1·30	Ngathaingyoung .	65	22·29	26·62	4·33
Zaloon ...	101	35·47	36·41	0·94	Mageelaha ...	87	16·39	21·51	5·12
					Zeebingwin ...	98	12·96	14·98	2·02
					Taboo ...	108	9·62	10·62	1·00

The difference at the Nawoon entrance between the 1871 and 1877 flood heights shows the direct action of the Irrawaddy in raising the Nawoon. A further influence must have been exercised owing to the changed conditions in the relations between the two rivers in the interval from 1871 to 1877. Not only was there the increase of burden carried by the Nawoon as measured at the Thapangyo gauge in the years 1872, 1875 and 1878 for the gauge readings up to the 1875 high flood level; but at the still higher elevation attained in the 1877 flood an immensely increased contribution must have arrived, due to the high flood passing over the open portion of the bank from Loodauzoo to Thambyading. The Okhpo small embankment and a light road constructed in 1875 in continuation of this from Okpho to Songong opposite Myogwin were both breached in 1877, some portion of the flood escaped through; but this was unimportant compared with the mass passing Myogwin. At this place the excess flood height of 2·83 shown by the gauge in 1877 at Myogwin may be taken to represent the final result of the action of the Irrawaddy on the Nawoon, uncom-

plicated by the embankment; and although the drainage from the 850 square miles of the upper watersheds enter the Nawoon above Myogwin, they only do so after spreading over the Myanoung plain and commingling with the Irrawaddy high floods.

Superelevation of the 1877 flood waves.

166. The differences between the Myogwin excess and that of the lower stations remain to be accounted for. These are as follows :—

Lèymyethna	...	...	0·45 feet
Zeebyogong	...	...	1·18 „
Ngathaingyoung	...	...	1·51 „
Mageelaha	...	...	2·30 „
Zeebingwin	...	...	0·00 „
Taboo ...	...	...	0·00 „

It may be objected that had the left bank of the Nawoon remained open to the flood flow the excess rise at Myogwin would, instead of increasing in the lower parts of the channel, have continually diminished in a similar manner to the Irrawaddy flood wave, where the excess of 1·72 feet at Myanoung fell to 1·30 feet at Henzada, and to 0·94 feet at Zaloon. This result would, undoubtedly, have been attained, had the Nawoon not received in this portion of its channel the drainage from about 900 square miles of watershed. And on the other hand, it is quite certain that the breaches in the embankment to the south of Myogwin, which were 15 in number, and which carried away a total length of the embankment of 5953 feet, had much effect in lowering the crest of the flood wave as it passed down the river. This will be separately considered in connection with the diagrams of gauge readings. At present the effect of the rainfall during the 1877 flood will be examined.

Rainfall on Nawoon Watershed in 1877.

167. The differences from the average for the year and for the several months for the same stations as before given are as follows :—

Table 44.

Difference of rainfall of the year 1877 *from the average.*

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Bassein ...	-0·25	0·00	-0·14	-1·02	-1·22	+17·63	+5·65	+12·16	-6·05	-0·71	-0·45	-0·03	+25·57
Henzada ...	-0·11	0·00	0·00	-0·56	-5·38	+3·52	-1·37	+4·70	-1·42	+2·38	-0·30	0·00	+1·46
Myanoung...	0·00	0·00	0·00	-1·70	-2·50	+4·80	-0·50	+3·75	-5·30	+0·50	+1·50	+0·20	-0·02
Rangoon ...	-0·06	-0·06	-0·08	-1·69	-11·17	+7·28	+0·67	+2·80	-1·74	+2·27	+1·50	0·00	-0·27
Sandoway...	-0·07	-0·09	-0·20	-0·78	-12·99	+6·95	+14·14	+24·52	-2·86	-3·84	+6·31	+0·09	+31·00

These stations, except Bassein and Sandoway, have the average rainfall for the year; while the former has 25·57 inches in excess, and the latter 31·00 inches also in excess. Bassein lies to the east, Sandoway to the west of the path of the monsoon current passing over the Nawoon watershed. For the first five months all these stations are in deficiency; while June has an excess fall which reaches 17·63 inches at Bassein. In July and August this station is still in excess by 5·65 and 12·16 inches, while Sandoway has excess falls of 7, 14 and 24½ inches for the months of June, July and August. The other stations remain close to the average.

168. It is to be regretted that no rainfall record was kept for any station within the area draining into the Nawoon, in former years. One has been established at Ngathaingyoung during 1879, which gives the local characteristics of passing showers. In default of this the Bassein records appear of the most value, as that town lies nearest to the watershed discharging into the Nawoon between Myogwin and Mageelaha. By these it appears that 7·85 inches more rain fell in June 1877 than in June 1871 ; 14·63 in July ; and 19·57 in August. The June rainfall would mostly have been cleared away before the July flood in both years. The actual excess fall on the 900 square miles of the lower Nawoon watershed was about 850 million tons in July, and 1130 millions in August 1877, over the same months in 1871. Distributed evenly over the whole of each month these additions to the discharge would have had considerable effect in raising the surface of the river in the 1877 high flood.

Comparison with 1871 rainfall.

169. Practically the excess rainfall came down in very heavy showers concentrated within a few days in each month. The daily rainfall records for these months given in Part II of this Report show that a series of heavy showers were widely distributed over the whole of Burma during these months. In July about 5, 8, 6, 5, and 6 inches fell at Sandoway on the 1st, 4th, 7th, 8th and 10th, while 4·19 and 4·76 are recorded there for the 28th and 29th. At Bassein 2·54, 2.54 and 2·28 inches were marked on the 9th, 10th and 11th ; and 3·9, 3·20 and 2·19 on the 18th, 19th and 24th. In August still heavier falls are recorded. Kyouk-phyoo had 6, 7, 4 and 12 inches on the 3rd, 4th, 5th and 6th ; and 5, 4 and 5 inches again on the 17th, 18th and 19th. At Sandoway 6·25, 8·80 and 11·34 inches were recorded on the 1st, 4th and 5th, and were followed by five other days of over 3 inches fall by the 22nd. Prome had 4·03 inches on the 19th ; and Henzada 4·28 inches on the same day. Bassein, which, perhaps, more truely represents the particular watershed considered, recorded 2·31 inches on the 3rd ; 3·10 on the 5th ; 5·91 on the 12th ; 2·51 on the 13th and 2·65 on the 21st ; with a further heavy shower, not repeated elsewhere of 4·76 inches on the 27th.

Heavy daily falls in 1877.

170. Each inch of rainfall implies over 64,000 tons of water thrown down on each square mile. Of the 900 square miles of the Nawoon watershed draining into the river between Myogwin and Mageelaha 220 are plain land lying for a width of four or five miles in width on the right side of the river. The whole of these plains become, during high floods, a second channel for the river discharge, in which the water flows to depths of from 10 to 20 feet at velocities of one to two miles and even more per hour, to rejoin the main channel of the river above Mageelaha. Every inch of rain falling directly upon this water surface must immediately raise the river by a corresponding height ; while, as already explained, the fall from the same showers upon the contiguous hills must when the ground is saturated be precipitated within a short time into the flooded region beneath. The hilly country is about 3 times the extent of the plains ; and if we assume that the rainfall in the mountains is heavier than in the lower lands, it may reasonably be supposed that after evaporation and other losses, the quantity of water reaching the river channel is, for every inch recorded, sufficient to raise the surface another three inches. In all, then, when the flood is high, and the entire plains are filled, each inch of rainfall recorded at Bassein, brings an additional elevation to the river surface above Mageelaha of four inches, within a short period from the time of the fall.

The connection between these falls and the flood rise.

171. While these figures have no higher value than as exemplifying the probable results, and have no claim to precision or accuracy, it will be necessary to recur to them and to use them when examining the record of the record gauge readings at the various stations on the Nawoon. These are reserved for a final discussion of the effects of the embankments ; but in order to use them effectively, it will

Value of the comparison.

be desireable to examine the further information obtained by gauging the Nawoon at difference places in 1878.

The 1878 flood.

172. In that year no extraordinary rainfall or flood took place. The embankments, though far from being in finished condition, had been sufficiently strengthened to withstand any ordinary flood. The differences from the average rainfall, with the daily falls at Bassein, Henzada and Myanoung from June to August are given in the following Tables :—

Table 45.

Differences of Rainfall for the year 1878 from average.

STATION.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Bassein ...	...	...	..	...	...	+1·61	−15·01	−0·97	−1·79	+10·55	−2·56	0·00	...
Henzada ...	−0·11	0·00	0·00	−0·56	−2·50	−0·30	−3·87	−5·53	−3·50	−3·58	−0·53	0·00	−13·32
Myanoung...	0·00	0·00	0·00	−0·40	+0·60	+2·30	−3·85	+0·55	+3·20	+0·30	−0·61	+0·70	+1·80

Table 46.

Rain-fall in 1878.

	Henzada. 1878.			Myanoung. 1878.			Bassein. 1878.			
Date.	June.	July.	August.	June.	July.	August.	June.	July.	August.	Date.
1	1·11	0·38	0·35	2·10	0·00	0·60	0·98	0·12	0·10	1
2	0·09	0·63	0·24	0·20	0·00	0·60	2·00	1·23	1·47	2
3	0·00	1·56	0·41	0·10	0·20	0·20	0·00	0·09	0·46	3
4	0·00	0·00	0·29	0·00	0·00	1·60	0·06	0·20	0·43	4
5	0·17	0·24	0·78	0·00	0·00	1·30	0·06	0·15	2·67	5
6	0·00	0·00	0·56	0·40	0·00	0·60	0·77	0·00	1·53	6
7	0·19	0·33	1·36	0·00	0·00	0·30	0·48	0·00	0·33	7
8	0·00	0·00	0·67	0·00	0·00	0·00	0·01	0·00	0·74	8
9	0·26	0·00	0·79	0·00	0·30	0·10	1·09	0·01	0·07	9
10	0·20	0·00	0·36	0·80	0·00	0·60	0·42	0·00	0·05	10
11	0·77	0·00	0·38	0·30	0·00	1·60	0·32	0·06	0·56	11
12	0·18	0·00	0·90	0·60	0·00	1·60	0·44	0·00	1·23	12
13	0·11	0·00	0·39	0·60	0·00	1·20	0·42	0·00	0·34	13
14	1·13	0·00	0·67	0·50	0·00	0·08	1·13	0·00	0·41	14
15	0·00	0·00	0·12	0·00	0·00	0·60	0·05	0·00	1·02	15
16	0·53	0·40	0·17	0·00	0·00	0·10	1·11	0·17	0·66	16
17	0·00	0·57	0·00	0·00	0·00	0·30	0·73	0·11	1·13	17
18	0·08	0·38	0·54	1·40	0·40	0·00	0·68	0·66	1·97	18
19	2·55	0·43	0·43	1·10	0·00	0·00	0·28	0·19	0·12	19
20	1·45	0·00	0·19	0·60	0·70	0·00	1·93	0·16	0·88	20
21	0·37	0·77	0·51	0·40	0·40	0·00	0·06	0·29	0·81	21
22	0·11	0·68	0·00	0·20	0·20	0·00	0·74	1·14	0·02	22
23	0·06	1·33	0·00	0·00	0·40	0·00	0·00	0·44	0·00	23
24	0·27	0·28	0·09	0·10	0·00	0·00	0·32	1·04	0·00	24
25	1·40	0·30	0·00	0·10	0·20	0·10	0·23	0·49	0·00	25
26	1·54	1·61	0·00	1·80	1·10	0·10	1·91	0·66	0·00	26
27	0·10	1·23	0·40	0·20	0·50	0·00	1·32	0·86	2·27	27
28	0·00	0·55	0·00	0·10	0·50	0·00	0·13	0·11	0·28	28
29	0·49	0·89	0·18	0·00	0·50	0·00	0·12	0·10	0·26	29
30	0·21	2·26	0·00	0·00	0·00	0·00	0·04	0·28	0·05	30
31	...	0·70	0·15	...	0·00	0·00	...	2·71	0·98	31
Total ...	13·37	15·52	12·43	11·60	5·40	11·60	17·83	11·27	20·84	Total.

Rainfall in 1878.

These tables indicate a rainfall somewhat below the average; with a marked absence of the heavy daily falls of the previous year.

Flood heights in 1878.

173. The flood rise marked the following heights above the sea in 1878 and in 1871. The column of differences is most instructive as indicating the result of the changes on

Table 47.

Station.	Date.	1878 High flood.	1871 High flood.	Difference.
Henzada —	7th August 1878.	40·58	42·48	−1·90
Nawoon-wa	7th do.	42·68	44·76	−2·08
Myogwin	7th do.	40·96	41·44	−0·48
Leymyethna	9th do.	32·87	32·16	+0·71
Zimbyogong	14th do.	29·07	27·86	+1·21
Ngathingyoung	15th do.	24·87	22·29	+2·58
Mageelaha	15th do.	20·05	16·39	+3·66
Zeebingwin	15th do.	14·32	12·96	+1·36
Taboo	17th do.	9·70	9·62	+0·08

the Nawoon in elevating the river surface. Although at the entrance from the Irrawaddy the Nawoon stood two feet lower in 1878 than in 1871, at Myogwin 8 miles from the Thambyading entrance the height was only 6 inches less. This first result can only be ascribed to the immensely increased supply through the Thambyading entrance. At Leymyethna the deficiency is changed to an excess of height, which continues to increase to Mageelaha where it is 3·66 feet; but a fall commences shortly below, and the river surface is almost the same as in 1871 at Taboo.

Discharge observations in 1878.

174. The records of the year 1878 might have been overlooked but for the fact that a series of observations for discharge were made in it; while the embankments near Mageelaha held good for the first time during flood; and completely retained the water in the river. The measurements made for discharge have been given in Table 38 of this report. The circumstances in which they were taken have been stated, but as some matters of importance remain to be brought out, the leading points may be here repeated. The discharge was gauged in August at Thapangyo, the old measuring station of the Nawoon, which is situated about 1½ miles below the junction of the two entrances from the Irrawaddy. It has there received the whole of its contributions from that river, and from its own upper watersheds. Only a very small portion of its burden can escape past this station in high flood without measurement. A second measurement of discharge was made simultaneously at Zeebingwin at the lower extremity of the embankment, and about 98 miles by river from the Thambyading entrance. No water escapes over the left bank between these two stations, while the embankment continues intact. But though the hilly ground comes down to the river on the right bank at different places above Zeebingwin, it recedes again opposite this village; and the writer found some portion of the discharge escaping measurement over the flooded low banks in August 1878. The quantity was not large as the current was very slow and the depth small. It will probably correspond in amount with that passing the Thapangyo station.

Remarkable results of the measurements.

175. As it was difficult to provide more than two measuring parties while the floods were up, the same persons were moved, the upper party to Leymyethna, the 31st mile, the lower to Payagyee the 90th mile of the river, for September. The mode of measurement was identical in all the cases; and was in the most elaborate form of surface and sub-surface velocity observations. Careful checks were made by superior officers with extensive experience on the former observations on the Irrawaddy. The calculations were worked out directly under the writer's supervision, and may be taken to be as accurate as this system of measurement permits. It is necessary to dwell upon this, as very curious

anomalies were presented in the results, which, from their amount, the writer at first thought must be due to error, but after a careful examination and revision of the whole of the original papers, including the velocity observations and cross sections and the detailed calculations, he is compelled to accept them as correct.

Comparison of the discharge at different points.

176. The totals of columns I and II of Table 38, show that some 600 million tons of water more than at Thapangyo passed down the Nawoon at Zeebingwin in August; and columns III, IV and V show that while 1,000 million tons more passed Payagyee in September than the computations from the scale give as passing Thapangyo, the river at the intermediate station of Leymyethna, where already two out of the five torrent streams from the Yomas have entered the channel, carried 1300 million tons less than at Thapangyo, and 2300 million tons less than at Payagyee. The missing quantity was so considerable that the writer had difficulty in believing that all this water could have escaped over the right bank in the 23 miles of channel between Thapangyo and Leymyethna. But a comparison of the whole of the cross-sections of the trunk of the river, with the knowledge that the Thapangyo section has enormously and rapidly increased in capacity in correspondence with the Thambyading entrance, while the lower sections cannot possibly do so for a long time, showed that such a result might have been expected.

The reservoirs on the western plains, and the flood waves.

177. The water commences to pass over the lower part of the right bank, where continuous erosion has opened out the lower plains by cutting away the elevated crest of the bank, and by the time the river has reached 35 and 36 feet on the gauges a considerable body of water has accumulated in the bottom lands and swamps of the plains. As the river continues to rise the flow increases both from the river to the plain, and through the plain parallel to the river; until, at highest flood, the surfaces of the channel water and of that on the plain are continuous. But in the different parts of the river there is a marked difference in the relation of the two bodies of water. From Myogwin southwards to Leymyethna there is always a flow from the river to the plain at all stages of the flood, when once it has topped the bank. From Leymyethna to Ngathaingyoung there is no connection between the water of the river channel and that of the plains, except at very highest flood, or when the gauges read 39 feet and above. To all appearance the channel here suffices for its burden; and the flow of the plain water is only manifest on examining it. From Ngathaingyoung to Mageelaha again the whole of the plain water is rejoining the river channel, or flows parallel and level with it until it re-enters the channel where this is restricted by the hills and by the embankments.

The 1879 floods.

178. The present section of the report had been written before the high floods of 1879 rose; but, as the June rise of the Irrawaddy in this year closely resembled in its magnitude and rapidity of elevation that of the year 1875, it was considered advisable to delay completing it until the features of the flood should have time to develope, so that any new matters of interest could be embodied in the report. Up to the present (September 1879) two great waves, each of them greater, at Myanoung, than the great flood of 1875 have passed down the river, and have not only offered a final test for the works, but have permitted conclusions of importance to be drawn regarding the changes in progress on the Nawoon. These will find place in the remainder of this section. One point to be noted is, that the remarks in the last paragraph, which were the results of an examination of the 1878 high flood, have just been re-verified. The writer has carefully examined again the whole of the different parts of the river, and the conduct of the flood discharge in the channel and in the plains. He found an extremely strong current setting over the bank from the river to the plain between Myogwin and Leymyethna when the gauge at both stations was between 38 and 39 feet. In some places the stream was over 3 and 4 feet deep on the

edge of the bank. Until the water rose to above 39 feet, the river remained within the banks from Leymyethna to near Ngathaingyoung; but south of this the water stood over the banks and flowed with a steady though slow current parallel to the river. It rejoined the channel, translucid and free from silt, above Mageelaha. The writer measured the velocity of the inflowing current at the village of Quinyah, and found it from one to two feet per second. It had a depth on the bank of 4 to 6 feet; while the gauge at Ngathaingyoung read between 39 and 40 feet. At Mageelaha itself the water entered the river from the plain on the left bank with a strong current of 4 or 5 feet per second.

Heights of the 1879 flood waves.

179. The data respecting the flood heights on the Nawoon for the season of 1879 are given in the following table :—

Table 48.

Stations.	1st Flood rise.		2nd Flood rise.		Difference of 1st rise from.		
	1879.		1879.		1871 Flood.	1875 Flood.	1877 Flood.
	Date.	Height.	Date.	Height.			
Henzadah	3rd August	43·13	...	...	+ 0·65	- 0·35	- 0·65
Nawoon-wa	3rd ditto...	45·20	3rd September	45·20	+ 0·44	- 0·50	- 0·90
Myogwin	4th ditto...	42·90	ditto.	42·74	1·46	- 0·30	- 1·36
Leymyethna ...	5th ditto...	34·24	5th ditto.	33·72	2·08	+ 0·33	- 1·17
Zimbyogong... ...	ditto ...	30·63	5th ditto.	30·07	2·77	0·52	- 1·25
Ngathaingyoung. ...	7th ditto...	26·62	6th ditto.	25·96	4·33	2·33	0·00
Mageelaha	ditto ...	22·68	ditto.	21·89	6·29	5·26	+ 1·17
Zeebingwin	8th ditto...	15·86	7th ditto.	15·23	2·90	2·50	+ 0·88
Taboo	9th ditto...	9·45	ditto.	8·95	(?)		

These figures express the final results to the Nawoon of the complex causes which have been operating for years to raise its surface. Before noticing them in detail, it is desirable to turn to the rainfall tables which follow to see that no exceptional rainfall has this year interfered with the results.

Table 49.

Rain fall in 1879.

1879	Myanoung.			Henzadah.			Ngathaingyoung.			Bassien.		
Date.	June.	July.	August.	June.	July.	August.	June.	July.	August.	June.	July.	August.
	In tenths		In tenths	In cenths			In cents			In cents		
1	0·4	0·6	0·3	0·11	1·23	0·89	0·68	1·06	0·34	0·15	1·07	0·11
2	0·0	0·2	0·6	0·39	0·22	0·86	0·31	0·10	0·63	0·32	0·22	0·32
3	0·8	0·0	0·8	0·12	0·60	1·25	0·11	0·53	1·55	0·03	0·19	0·18
4	0·5	1·7	0·0	2·30	1·46	0·46	3·02	2·40	0·25	0·33	0·49	0·71
5	0·0	0·3	0·1	0·01	0·61	0·18	0·10	0·75	0·22	3·31	0·83	0·20
6	0·0	0·1	0·1	0·27	0·89	1·53	1·55	1·81	1·96	0·69	1·14	0·04
7	0·0	0·0	1·3	0·00	0·37	0·20	0·01	0·85	1·62	0·92	0·57	1·02
8	0·3	0·0	0·5	1·35	0·34	0·96	0·73	0·50	1·05	0·00	0·86	2·12
9	0·9	0·0	0·3	0·14	1·68	0·23	0·39	0·77	1·07	0·55	1·52	1·12
10	0·8	0·2	0·1	0·11	0·15	0·25	0·35	0·49	0·60	0·09	0·89	0·40
11	1·0	1·0	0·0	0·75	2·43	1·07	0·48	2·10	0·91	0·70	0·96	0·06
12	0·1	0·2	0·2	0·12	1·34	0·34	0·12	1·45	0·30	0·37	1·04	0·22
13	0·0	0·6	0·1	0·05	0·55	0·12	0.08	0·95	0·06	0·41	1·47	0·29
14	0·0	0·3	0·4	0·02	1·10	1·62	0·12	0·50	1·12	0·22	0·50	0·57
15	0·0	0·4	1·0	0·70	1·82	0·14	0·10	0·75	0·45	0·00	0·05	0·30
16	0·0	0·9	0·7	0·16	1·07	0·12	0·29	0·20	1·80	0·43	1·15	2·99
17	0·7	0·2	0·6	0·11	0·71	1·16	0·17	1·03	0·18	0·68	0·09	0·43
18	1·2	0·0	0·0	0·21	0·58	0·00	0·01	1·53	0·21	0·19	0·27	1·36
19	0·3	1·1	0·0	0·36	0·56	0·29	0·13	0·03	1·02	0·11	0·02	0·15
20	1·5	1·7	0·4	0·49	0·45	0·19	0·71	1·37	0·49	0·09	2·52	0·02
21	0·2	0·0	0·6	0·00	0·60	1·48	0·12	0·00	0·65	0·12	0·77	0·46
22	1·2	0·0	1·2	0·04	0·00	1·34	0·80	0·00	1·75	0·04	0·19	0·99
23	0·4	0·0	0·5	0·18	0·36	0·38	0·21	0·00	0·78	0·74	0·17	0·84
24	0·4	0.7	0·2	0·31	0·00	0·12	0·49	0·45	0·21	1·42	0·00	0·59
25	0·0	1·0	0·0	0·95	1·40	0·30	0·60	0·00	0·00	0·59	0·08	0·34
26	0·7	0·0	0·0	1·27	0·00	0·00	1·61	0·01	0·00	1·77	0·03	0·00
27	1·6	0·0	1·1	1·32	0·00	0·27	1·20	0·41	0·04	0·67	0·06	0·06
28	0·4	0·0	0·1	2·82	0·00	0·00	2·01	0·03	0·00	1·10	1·03	1·21
29	0·1	0·8	0·2	0·49	0·25	0·20	0·16	1·70	0·20	1·07	0·18	0·32
30	0·7	0·7	0·3	0·24	0·19	0·14	1·28	0.22	0·25	1·20	0·17	0·01
31	...	0·9	0·1	...	0·46	0·63	...	0·21	0·11	...	1·12	0·48
Total	14·2	13·6	11·8	15·39	21·42	16·72	17·94	22·20	19·82	18·31	19·65	18·91

180. Ngathaingyoung appears for the first time in the rainfall records. It corresponds fairly on the whole with Bassein on the one side and Henzada on the other. The northern stations Myanoung and Henzada are somewhat above their average, while Bassein is rather below its usual supply. The only noticeable feature in the rainfall is that from the 20th July towards the latter end of the month there was a very slight fall at all the stations; but the earlier part of August had an increase. This will be particularly noteworthy in considering the gauge diagrams for the Nawoon.

Comparison of the 1879 and 1875 floods on the Irrawaddy.

181. The 1879 floods have been most valuable in affording a comparison with the 1875 floods; as, on the main channel of of the Irrawaddy from Saiktha southwards, there were only a few inches of difference between the heights. The upper stations show a slight excess, and the lower ones a slight deficiency in height. At the Nawoon entrance the 1879 flood marked 6 inches less than the 1875 one. The writer measured the height of the flood above bench marks to the south of the villages of Noukmee and Thambyading. At the former it stood at 46·32, at the latter 45·04 feet + M. S. L. These figures are much lower than the assumed height, 47 feet, for the 1871 flood at Thambyading. Indeed, the last one is below the measured height of the Nawoonwa gauge, 45·20 feet for the same flood, although this is 3 miles lower down the Irrawaddy River. The only explanation that can be offered for this anomaly is, that both the bench marks lie on ground far removed from the present main channel of the Irrawaddy, which has there made the set to the east before described, leaving these places standing on what will before long be an abandoned lagoon of the river. The change is most important, as it indicates a much smaller high flood supply to the Nawoon; and, by lowering the slope, has lessened the capacity of the Thambyading. It is thus certain that the change tending to a diminished supply to the Nawoon has already commenced, and that, beyond the spill over the bank near Loodauzoo, there can be no further additions to its burden.

Comparison in the Nawoon.

182. In comparison with the 1871 flood at all the stations, the 1879 one shows an excess, commencing with 0·44 feet at the lower entrance; and, after marking 1·46 feet at Myogwin, reaching to no less than 6·29 feet at Mageelaha. It then falls to 2·90 feet at Zeebingwin, and to nothing at Taboo. These last stations were not actually marked, in 1871, so that the data for that year are open to doubt; but what is of more importance is the fact that the elevation of the surface is proved to be quite local; and the enlarged tidal portion of the channel appears capable of carrying the increased flood discharge without a great rise of surface. The 1879 flood was lower than that of 1875 by 0·30 feet at Myogwin. At Leymyethna it stood above it by 0·33 feet; and this excess continued to increase till it reached 5·26 feet at Mageelaha, the culminating point of the super-elevation. This excess must be taken as a truer index of the result of the changes on the Nawoon than that over the 1871 flood. The 1877 flood line runs nearly parallel with that of 1879 as far south as Zimbyogong; and it would seem that only at this point commences the elevation due to the embankments continuing successfully to restrict the flood discharge to the river. At Ngathaingyoung both floods reached exactly the same height; but at Mageelaha the 1879 one surpassed even that of 1877 by 1·17 feet, thus proving that the breaching of the works in the earlier year lowered the surface of the Nawoon considerably.

The secular surface of the Nawoon during the floods.

183. We have now passed in enumeration all the elements concurring to the results arrived at on the Nawoon in the elevation of its surface. Some of the simpler comparisons and contrasts have also been made; and though the subject is far too complex, and the efficient agents too varying and commingled ever to permit a just appreciation of the several effects, it is still possible to deduce a clear idea of what the different causes are, and how far

they enter severally or united as factors in each year's flood rise. The features of these flood rises are accurately given in Plate XXIX for the years 1875-1879 for each of the stations at which gauges have been regularly recorded as the embankments were extended. A comparison of the flood waves with each other was made in Plate VI, but the further information required, and the importance of showing out the results in as exhaustive a manner as possible justify the addition of another plate. In this the heights of the river surface are shown for the six rainy months for each day, and they are reduced to the datum of mean sea level, as this permits each line to stand out distinct, and to show the changes in the form of the flood wave on its passage down the river.

Changes on the channel of the river shown by the flood rise.

184. For the year 1875 only three stations were recorded *viz.*, Myogwin, Leymyethna and Ngathaingyoung. In 1876 seven stations are shown from Myogwin to Taboo; and the later years include the records of the Nawoon-wa gauge. A dotted line for each year gives the rise and fall of the Irrawaddy at Henzada for comparison. The first point for enquiry is:—Is it possible to learn from these gauge records what effect the continuous enlargement of the Thambyading entrance, and the steady and enormous increase in the supply from the Irrawaddy to the Nawoon had on the latter river, independently of the embankments. The best means of answering this appears to be to make a comparison of the 1871 flood rise with that of succeeding years. The 1871 flood is the first regarding which we have any accurate data upon the Nawoon. Its height is the very best datum for comparison, as it rose universally one or two feet over the high land on both banks of the Nawoon, and was almost everywhere parallel with this. It thus represents the height at which cultivation is ruined on the banks; and as it occurred with what must now be looked upon as a moderately high flood unmodified by any action of the embankments, its highest levels will serve as data by which to test the succeeding flood rises in the river.

The 1871 flood level.

185. The 1871 flood occurred before the embankments were extended down the Nawoon river, and before the changes in the size of the Thambyading had made it acquire the enormous preponderance of supply which it has subsequently held. The rise of later floods below and up to the 1871 levels must be principally due to the increased volume of water brought by the Thambyading; as the discharge, while it continues within the channel, cannot be restricted in any way by the embankments which stand above the left bank. A certain amount of restriction would be exercised by closing the various creeks which opened from the river to the country on this bank, and which took off a portion of the burden at heights below high floods. But these creeks are few in number and insignificant in size; as on the 70 miles of embankment there were not more than 5 or 6 streams larger than 50 feet in width, or 10 or 12 feet in depth. A few of smaller size existed, but the action of the whole number in relieving the river was of the slightest. If, then, we can ascertain the nature of the change brought about in the channel below the 1871 flood level, this will represent the share in the increased burden has had in raising the surface.

Dates of subsequent flood waves reaching the same height.

186. In the Nawoon flood diagrams of Plate XXIX a line has been drawn to each curve to represent the 1871 flood height at each station. It intersects the curves on the day when the water actually rose to that height at the place. In 1871, although no record exists of the passage of the flood wave down the river, it is known that it first rose at the upper stations, and its crest then passed down the river, attaining its highest point at the lower stations on subsequent days. This has been the invariable history of all the ordinary flood waves both on the Irrawaddy and on the Nawoon. The following table gives the dates for the several years at which the 1871 flood height was marked at each station.

Table 50.

Stations.	1875.	1876.	1877.	1878.	1879.
Nawoon	...	...	11th August...	...	31st July.
Myogwin	12th August...	...	8th „ ...	...	24th „
Laymyetna...	6th July ...	21st July ...	6th „ ...	2nd August...	5th „
Zimbyogong	...	20th „ ...	5th „ ...	28th July ...	2nd „
Ngathaingyoung	6th July ...	18th „ ...	1st „ ...	27th „ ...	30th June.
Mageelaha	...	...	3rd „ ...	1st August ...	5th July.
Zeebingwin	...	...	5th „ ...	6th „ ...	7th „
Taboo	...	...	11th „ ...	...	...

The channel of the Nawoon at Ngathaingyoung is less enlarged than elsewhere.

187. In 1875 only 3 stations were recorded, and the river is shown to have risen to the 1871 flood level at the two lower ones of Leymyethna and Ngathaingyoung 6 days before it reached that height at Myogwin. In 1876 the river did not rise so high at this place, but it reached the 1871 level first at Ngathaingyoung on the 18th July, then at the next higher station on the 20th, and Leymyethna, still higher up the river, on the 21st. The 1877 record is the most complete. The 1871 flood level was marked first at Ngathaingyoung, the station about half way down the river, on the 1st August. The river rose on the 5th to the 1871 flood height at the upper station of Zimbyogong about 27 miles off by river, and on the same day at Zeebingwin 33 miles below. On the 11th August the flood rose to the 1871 height both at the Nawoon entrance 68 miles above Ngathaingyoung, and at Taboo 43 miles below. The two succeeding years show Ngathaingyoung to retain the priority of flood elevation to the 1871 height; the 1879 rise being remarkable for the long interval between the rise at that place and at the Nawoon entrance; while at Taboo the lowest station the 1879 flood does not appear to have reached the 1871 flood height. There is, however, uncertainty about this, as the 1871 flood was not recorded there at the time of occurrence.

Enlargement of channel above that place.

188. The explanation of this singular series of phenomena lies in the fact that the continuous increase of burden brought by the Thambyading for many years past has caused an excavation and enlargement of all the upper parts of the trunk. The comparative sections given for Thapangyo and Leymyethna for 1872, 1875, and 1878, with the discharges, prove this process to have been in operation there, but it does not appear to have affected the trunk at the lower stations in anything like the same degree as at the upper. The river at Ngathaingyoung has increased very little in size; though there is reason to believe that even here there is a slight enlargement. The river south of Ngathaingyoung follows the normal law of the flood waves passing lower points at later dates.

Proof that the whole land would have been submerged but for the embankments.

189. And this result proves that from this cause alone the whole of the land on the borders of the Nawoon river would have been yearly submerged by floods of the height of the 1871 flood, which destroyed all cultivation, irrespective of the construction of embankment works. In each of the years 1877, 1878 and 1879, when the water had risen to the 1871 flood height, and the water was passing over the banks throughout the middle of the trunk as far north as Leymyethna, the river sur-

face stood about 2 feet below the 1871 mark at Myogwin, and three feet at Leymyethna. This the gauge diagrams show at once. In all the part of the river referred to the low plains on the right bank were far from filled, and the flood could escape freely into them at the dates given. The result would thus have been the same whether the embankment were there or not; and at least 3 feet of the elevation of surface now known in the river between Zimbyogong and Zeebingwin, is solely owing to the natural enlargement of the upper channel in consequence of the formation of the Thambyading bend.

The gauge diagrams of secular surface of the Nawoon.

190. The portion of the elevation due to the embankments is equally traceble from the gauge diagrams. These give a complete history of the secular surface of the river; and, in conjunction with the regular taking of cross sections on the various lines already measured, will permit comparisons to be made at any future time by which to test the further changes in its channel. The 1877 and the 1879 curves are the most instructive; but certain features are common to each year's set. Thus there is a marked difference in the extent of the variations of the three curves of the mid-trunk at Leymyethna, Zimbyogong and Ngathaingyoung, and of those of the stations above and below them; while there is a striking correspondence between the whole of these three curves for the entire year, as they remain, with a few exceptions, nearly parallel throughout. These stations represent the portion of the trunk where the conditions have been least changed, whether by the embankments or by the enlargement.

The three stations of the mid-trunk.

The secular curves for the upper stations and for Henzada.

191. The curves for the upper stations of Nawoon and Myogwin follow closely the variations in height of the Irrawaddy. This is shown by the Henzada secular surface drawn in dotted lines; and which corresponds with the Myogwin secular surface, although it has a somewhat wider range. The Nawoon entrance gauge is not recorded for the lower levels of the river, as the stream is closed; and when the water first appears on the gauge, it comes round by the Thambyading past Myogwin, and stands at the same height as at this place. When the water enters direct the gauge readings run nearly parallel to those of Henzada. The Nawoon river surface is here comparatively little affected by local rainfall, and less by the embankments. The former are moderated in the spread of the Myanoung plain; which also prevents the restrictive effect of the embankments being felt north of Thapangyo.

The curves for the lower three stations.

192. The lower three curves of Mageelaha, Zeebingwin and Taboo embody more fully than the rest the results of the changes on the river, and also reveal when contrasted with the other curves the changed conditions of the channel itself, in its tidal portion and in its trunk. It is noticeable that all three correspond in the range and character of the variations of height much nearer with the two highest curves than with the three of the mid-trunk. The reason of this is obviously the fact that when once the right bank between Myogwin and Leymyethna is topped, the crest of the flood wave is cut off in a great measure throughout the mid-trunk, the surplus being thrown into the low plains. The mid-trunk thus continues full up to the brim, and simply passes on the discharge remaining in it, until the plains on the right bank are also filled and rise level with the river. Then every impulse felt above is regularly propagated throughout the river length.

The 1877 secular curves.

The 1877 secular surface curves show this action of the western plains clearer than those of other years. There is a filling of the mid-trunk of the Nawoon early in July, when the water rose to the 1871 level at Ngathaingyoung and Mageelaha. The effect of the increased supply is made evident by the comparatively rapid rise at the lower stations so long as the water remained within the channel. A small portion of the wave crest passed into the plain, when the water sank again; and as it commences to pass over the lower

parts of the bank when the surface is between 2 and 3 feet lower at Myogwin and Leymyethna, some must still have been escaping when another rise commenced about the 23rd July for the great rise of the year. At Myogwin the river rose 4 feet in 8 days. At Leymyethna the rise in the same time was about 20 inches. At most of the lower stations it was less than one foot; Mageelaha being peculiar in rising only on the 26th and 27th; and then continuing at the same level for six days, when it suddenly responded to the continuous increase at Myogwin, and rose 5 feet in 5 days, while none of the other stations above it rose more than 2 feet in the same time.

The wave crest and the western plains.

193. When the river surface rose to the level of its bank by the 26th July all the flood wave crest was cut off and passed into the plain north of Mageelaha, so that no share of the rise was felt at this place till the 2nd August, when the water of the plain had found its way to the same point; and as the river continued to rise at all the upper stations the flow rapidly increased till the plains became a second river bringing an enormous volume to Mageelaha independently of the river channel. The measurements made for discharge at Thapangyo, Leymyethna, Payagyee and Zeebingwin in 1868 show what a large amount of water is lost to the mid-trunk when the gauges read about 37 or 38 feet, or a little below the 1871 level. A daily average of over 40,000,000 metre-tons is deficient at Leymyethna or about $\frac{1}{6}$th of the whole discharge at Thapangyo. When the river rises still higher, and before the plains are filled, the loss must be much larger; but we have no measurements to show what the quantity is.

The breaches in 1877.

194. But without that knowledge the indications given are valuable. The history of the breaches in 1877 explains some features of the secular curves, especially those of the lower stations. A list of these with the dates when they were first formed and the magnitude they ultimately assumed is given in Table 51 below.

Table 51.

Mile of Embankment.	Date.	Final Width.	Depth of water on ground.
5 and 6 Furlongs	19th August	200	5
25 „ 4	20th „	175	5½
33 „ 2½	22nd „	186	5½
37 „ 0	19th „	358	6½
53 „ 0	19th „	150	4½
54 „ 4	19th „	1,620	7½
57 „ 1½	19th „	28	6
57 „ 2½	19th „	25	7½
57 „ 4½	19th „	1,360	8½
58 „ 4½	8th „	820	8½
59 „ 4½	19th „	180	8
59 „ 6½	19th „	726	6½
60 „ 3	19th „	20	5½
60 „ 6	19th „	114	5½
60 „ 7	19th „	160	5½
61 „ 3	19th „	41	4

195. The total length of the breaches from the 25th mile southwards was nearly 6,000 feet. The depth of water ranged from 4 to 9 feet against the embankment, but that passing through must have been much greater, as in several of the breaches the ground was excavated many feet deeper. Only two of these occurred before the 19th August; viz:—that on the 58½ mile on the 8th, that on the 57½th mile on the 10th. Mageelaha is near the 60th mile. There does not appear to be but a slight effect on the gauge reading there produced by these breaches; and it is rather a pause in the continuous rise than a fall. But the effect on the 19th of the breaches extending from the 53rd to the 61¼ mile is unmistakeable. Although the Irrawaddy continued rising, and the Nawoon at all the higher stations shows an increase of height till the 21st, a sudden fall of nearly 1½ feet is marked at Mageelaha, evidencing the relief afforded by the breaches. How high the river would have gone were it not for this can now only be conjectured; but the 1879 flood, which stood over 1 foot lower at Myogwin, marks 1·17 feet higher at Mageelaha.

The effect of the breaches in the river 1877.

196. The immense local rainfall which was synchronous with the arrival of the great Irrawaddy flood wave is more responsible for this immense rise in 1877 on the Nawoon than the Irrawaddy rise. The Henzada gauge shows the, for that place, immense fall of 4·28 inches on the 19th; while Prome has 4·03 inches. Henzada lies directly in the path of the south-west monsoon after it has crossed the local watershed discharging into the Nawoon above Mageelaha, and perhaps represents better than any others the much more intensified fall that took place on the same day over that area. Twelve out of sixteen of the breaches on the Nawoon occurred on that day; and that the immediate cause was mostly local is proved by the fact that the Irrawaddy at Henzada was lower by some inches on the 19th than it had been on the 15th. The most marked rise took place at Zimbyogong of 1·17 feet on the 19th and 20th. This place is in the mid-trunk and not near any important torrent. The river was even with the plain in the water surface, and the heavy fall of rain recorded at Henzada would just pass over the place, and be added at once to the flooded surface.

The effect of the rainfall in the river in 1877.

197. The 1878 secular curves show little that is remarkable except perhaps the immediate response of the Mageelaha variations to those of Myogwin, when once the plain is filled, while the intermediate stations of the trunk vary but little. During the first flood rise of this as of other years the curve at the upper stations is convex upwards, while the three lower stations are concave, until the water of the plain reaches Mageelaha. In the October fall and rise, the three mid-trunk stations vary only about one foot, while Myogwin above and Mageelaha below vary over 3 feet, as the plain channel ceases and resumes action. No-strain was put on the embankments, in any part, during this year's flood, which remained everywhere below that of 1877.

The 1878 curves.

198. An effort was made to entirely finish the existing portion of the Nawoon embankment before the 1879 floods came; and urgent representations were made to procure a further sum in addition to the allotment for the year 1878-79, which had been expended, and had left the works weak and deficient in height. A sum of Rs. 26,239 was still required to raise the Nawoon embankment to a height of 3 feet above the 1877 flood mark from the 40th to the 60th miles, and of 2 to 2½ feet in other parts; and to give it the requisite strength. Permission was at last obtained early in February to spend the money; but at this time of the year (1) all the immigrant coolies have gone away; the hot weather is about coming on, and labor of any kind is procurable with difficulty.

The condition of the embankment during the 1879 floods.

(1.) Letter No. 287 of 17th March 1879 reported the impossibility of getting labour on this work. The total amount spent out of the Rs. 26,239, at the end of June 1879 was 13,264 Rs.

As a consequence the desired work was still unfinished by June, and when the flood rose the Nawoon embankment was partially unraised on the 42nd mile, on the 47th and 48th where it passes through the town of Ngathaingyoung, and on the 58th miles. It was also deficient in section on a few other places; but generally, it was finished to the requisite height and strength.

The two flood waves in 1879.

199. The flood of 1879, although it did not rise so high at either the Nawoon entrance, or on the Henzada gauge, was on the whole Irrawaddy line, somewhat higher than the great flood of 1875, while it fell short of that of 1877. The changes in the main channel of the Irrawaddy near the two entrances of the Nawoon have resulted in a considerable lowering of the flood height there, and consequent diminution of supply. The writer measured the flood works of the 1879 August rise above masonry bench marks near Noukmee and Thambyading, and found them lower by 0·68 feet and 1·96 feet respectively than the conjectural height of the 1871 flood. At the Nawoon-wa entrance, the water rose on the 3rd August, and again on the 3rd of September to 39·50 feet on the gauge, or exactly 6 inches below the 1875 flood mark. Two great flood waves occurred, the heights of which have been already given in Table 48. But the extraordinary feature of these is that the second wave was the highest at all the Irrawaddy stations; without exception, but for some reason the second wave on the Nawoon continued lower throughout all its length below the Nawoon entrance. At Myogwin it was 0·16 feet lower; at Leymyethna 0·52; at Zimbyogong 0·56; at Ngathaingyoung 0·66; and at Mageelaha 0·79 feet.

Explanation of the differences of rise. The rainfall.

200. The first explanation must be sought in the local rainfall. This, as given in Table 49, was 21·42 inches at Henzada, 22·20 at Ngathaingyoung and 19·65 at Bassein for the month of July; while 16·72, 19·82 and 18·91 inches are the respective fall for August. Ngathaingyoung reads slightly higher than either of the other places, which seems to indicate that the Nawoon watershed has a heavier rainfall than it has been credited with. The difference of 2·38 inches of rain between July and August would certainly give a smaller supply to the Nawoon for the second great rise, but is hardly sufficient to account for the whole disparity in the height of the waves.

The influence of the western plain.

201. It is requisite to recur to the secular surface curves of Plate XXIX where it is seen that the river fell at all the stations between 6 inches and one foot lower during the middle of August than in July. In this variation it followed the Irrawaddy at Henzada. The principal effect of this was to lower the Myogwin and Leymyethna gauge readings to below the 1871 flood mark; and to diminish enormously the spill between those stations over the right bank of the Nawoon to the great plain reservoir north of Mageelaha. This accordingly had time to empty itself and leave a large storage space to relieve the second flood rise. To this rather than to the rainfall, is to be ascribed the difference between the two waves. This conclusion conducts to a truer conception of the actual effect of these plains as a moderating reservoir in their action on the discharge of the Nawoon at different points.

Intensification of the flood at Mageelaha through the plain reservoirs.

202. So long as these plains have any capacity left to receive a portion of the flood wave passing down the Nawoon they serve to lower its crest rise and to diminish the rate of discharge at all the lower stations. This is evident, not only at all the intermediate stations, where the flood rise is never so great as it would be were the water confined to the channel, but at Mageelaha where the restriction to the river channel is now almost complete. At the intermediate stations, therefore, the action is entirely beneficial; and it is so at the lower station for all but extreme flood rises supervening on the plain reservoir already filled by previous floods. The great excess of elevation in 1877 and in 1879 shown at Mageelaha, where the wave crest rises so high in the secular curves, is due to the great body of the water which has been accu-

mulating and slowly passing down the plain on the right, suddenly appearing and flowing into the channel over a length of many miles of bank north of Mageelaha. It is probable that this produces a higher rise than would have occurred had double embankments been constructed on the whole river length, as the surplus water would have passed away more rapidly. The moderating plains, therefore, appear to lower the flood rise on the upper and mid-trunk of the Nawoon ; but intensify it in very high rises at Mageelaha.

The excess elevation of river surface in 1879.

203. The total super-elevation of surface at Mageelaha in 1879 over the 1875 flood was 5·26 feet ; and over that of 1871, 6·29 feet. Admitting the first mentioned to be the true result of all the causes tending to raise the Nawoon river surface above what it was in 1875, we have here nothing of an alarming kind, even if it were the result of the embankments alone, instead of being, as it is, the complex product of several different causes.

Justification of the embankment works.

204. Had the same raising of the surface resulted throughout the whole length of the channel, and, if double embankments had been constructed, something less than that surface elevation would have been produced, the result in the protection afforded to the country and the financial returns would have justified the undertaking of the works. The mere raising of the embankments a few feet is an easy matter if the money be provided. And it would be as easy to keep a wave with a few feet higher crest to the channel with stronger embankments, as it is to hold the present waves.

Impossibility of discerning the amount of elevation due to the works; but the results are satisfactory.

205. In finally judging of the action of the embankments in raising the Nawoon surface the effect of the abnormal increase of the rivers burden since 1865, with the changing capacity of the river channel, the extraordinary local rainfalls, and flood impulses from the Irrawaddy river should be eliminated. Probably it would be found, if a direct comparison could be made between two such floods as those of 1875 and 1879, with the river in good condition and regular action, its channel sufficing or almost sufficing to carry the burden furnished to it, that the super-elevation would be trifling, and in place of being between 5 and 6 feet, that it would be at most 2 or 3 feet. Such a comparison cannot now be made ; but considering the great changes in the régime of the river, and the large proportion the excess supplies thrown into it bear to its former discharge and present capacity, the excess elevation of 5·26 feet must be acknowledged to be small and to be a most satisfactory result, fully justifying all the efforts and expense which have been made to secure the welfare of the country.

Further consideration of the results of the breaches in 1877.

206. It remains to be considered, what is required to render the works free from further danger, and to obtain the full benefits offered by these embankments. Little is to be learnt from the 1877 flood alone, as the want of preparation in the works rendered them susceptible to damage if any rise greater than ordinary occurred. The list of the breaches with the dates on which they happened prove the hopelessness of attempting any extemporized measures to meet a sudden flood rise. Twelve breaches opened on the same day over a length of 60 miles ; most of them so widely that nothing could be done to remedy them. A few of the smaller ones were closed at once. With all the breaches above the 50th mile the water passed almost immediately into the ample drainage channels of the interior after damaging a few hundred acres of the lower lying rice land just behind them. When the August flood wave fell, temporary dams were thrown up in front of the opening consisting of a double row of piles and bamboo matting from 4 to 5 feet apart. These were stayed and strutted, and the interval filled with puddled clay. In almost all these cases the damaged fields were replanted, and though the harvest was not so rich as it would have been, very little loss resulted. The lower breaches were too extensive to be entirely closed. When they first oc-

curred the country inside resembled a huge lake of water where lately fields of green rice had been seen. No injury whatever was experienced by other property, or by houses or cattle. No lives were lost. Colonel Davies, the Deputy Commissioner, who was present with the writer at the time, sent boats to render help to persons who he had heard were refuged in trees as their houses were under water. They declined all aid, having made themselves comfortable, with their cattle, on stages resting on the tree branches, and calmly awaited the subsidence of the waters. When these fell the greater part of the breaches were temporarily closed, and a large portion of the fields were again planted.

The desirability of changing the Financial arrangement for such works.

207. If any lesson may be drawn from that year's experience it is this, that when any additions or alterations are required to existing embankment works, and the necessity of carrying these out is admitted, the work and the expenditure should not be distributed over a series of years; but should be concentrated on a single season. The money spent in raising and strengthening the Nawoon embankment previous to the 1877 flood was inadequate, and was known to be so. The work was incapable of supporting the pressure, and yielded; the only results of its having been strengthened being that the breaches destroyed a more expensive piece of work. The cost of the repairs to the three breaches in 1876 was Rs. 4,016. The cost of repairing the 16 breaches on the Nawoon in 1877 was Rs. 33,677; all of which was a total loss; but which would have been saved if the work had been properly finished within the first year after its necessity was made apparent.

The 1879 flood and the embankment.

208. The embankment had a narrow escape from being breached in 1879 from the same cause. When it became evident early in March that the money allotted for the work had come too late in the season to be utilized, care was taken to turn the available labour to the weakest parts. All of these were taken in hand and rendered quite safe except the 58th mile. The 42nd mile, although low, was very strong, being composed of good clayey loam which had in some measure sunk, but had acquired strength in sinking. The 47th and 48th miles are a comparitively light work running through Ngathaingyoung. Not more than 5 or 6 feet of water can stand against the embankment there; and, at present, a marginal embankment runs along the river in front and keeps all the water away. This last work is in a precarious condition. There is not sufficient room between the houses and the river to build a substantial work; and the river threatens continually to undermine it, so that its going is a question of time. It had been found impossible to get any labour to raise the embankment in Ngathaingyoung in the working season; even the vagrants belonging to the town refusing to help; while the better-off residents considered it beneath them to aid in their own protection. No effort was made by the embankment officers to bring the labour available elsewhere into the town, as it was more urgently needed on the weaker lengths of work, and a weapon was in reserve which promised to be useful should the raising of the town embankment become urgent.

The Burmese embankment Act.

209. This weapon was the Embankment Act, the necessity for which was made apparent in the floods of 1875; and which, after some delay, became law in 1877. The Act is given in Appendix I. One clause in it prevented its being legally applicable during the floods of 1877. This was the clause prescribing that the names of all persons liable to be called out under it should be drawn up in rolls and submitted to the Government for approval before they were forced to labour. Although a large number of persons were requisitioned in 1877 under the authority of the Chief Commissioner, none were prosecuted, and only moral influence was used. This would not have been of much use if the persons requisitioned had known that there was no legal sanction for the forced labour. But the simultaneous occurrence of the breaches mostly without warning rendered all efforts to prevent them useless; and the people generally were willing enough to help to temporarily close them.

210. It is different when to the uninitiated no signs of danger exist. The agriculturalist is thankful enough for the protection of the embankment and appreciates it thoroughly; but as long as no actual breach is imminent, or has occurred, he is naturally unwilling to leave his fields at the very time ploughing and planting are in progress. But when the river marks over 39 feet on all the gauges, and continues steadily rising, danger is at hand. Leaks break out and must be sought for, as, if left uncontrolled for a time, they increase in size, and though at first clear water issues, mud and earth soon begin to appear, furnished by the embankment itself or by the ground on which it stands. If these leaks are found and dealt with in time, they are easily managed, by forming a well, or half-well around them and raising a small earthen wall round the whole, so as to permit the water to flow freely but with small velocity. When neglected, however, these leaks are a source of the utmost danger to the embankment; and while in ordinary times a gang of two or three men to the mile is employed during floods to keep all in good order, it is necessary when the height of the water is at danger to double or even treble this number to have men at hand not only to find the leaks but to treat them as described. Not a single man beyond those regularly employed could be hired for any reasonable sum of money on the Nawoon side. The Act authorizes the Embankment Officer, when he considers the works in danger, to levy as many of the persons, able-bodied men of the laboring class on the list mentioned, as he considers necessary to aid in protecting the works. Experience has proved that a rising river with a 39 feet gauge means danger, which becomes extreme when 40 feet is passed, even if no trace of leaks or other weakness appears.

Necessity of recurring to the Act in 1879.

211. The lists had all been prepared by the Deputy Commissioners of Bassein, Henzada and Thonkwa through whose districts the works run, the latter only for a few miles. The two former officers, Colonel Munro and Major Spearman, who, from the important influence of the embankments on the revenues under their charge, were closely interested in the result, had taken every precaution to secure the proper working of the Act, which, when news from the upper Irrawaddy stations made a great flood on this river and on the Nawoon highly probable, was proclaimed by the writer, as Embankment Officer, for the Nawoon on the 14th July, for the Irrawaddy on the 26th, a specific proclamation being requisite in each case when it is employed. Instructions were telegraphed to call out sufficient men to put the 42nd and 45th miles of the Nawoon in as safe a condition as possible, and the writer proceeded to Ngathaingyoung to see that these were carried into effect.

Preparations for applying the Act.

212. The Nawoon had risen at this place to 39 feet early in July and even reached 40 feet; but as special precautions had been taken for this part where the super-elevation due to embankment restriction was apprehended, no fear was felt. But telegrams from Thayetmyo sent daily from the 24th July showed that the river was rising there with extreme rapidity, and threatening to exceed the great rise of 1877. On the 26th it was only 4 feet below this, having risen over two feet in two days. This rate promised to continue, as the rise of the 27th was 10 inches; and the 1875 and 1877 floods having proved that the Nawoon would respond to the Irrawaddy, no further delay with the Nathaingyoung town embankment was possible; and a requisition was made at first for 200 men, and afterwards for another 400. The requisition was made through the Magistrate, Mr. Martyr. No difficulty whatever was experienced in getting the people, one or two who pleaded illness or incapacity were let off. The rest were given tasks of ten feet in length each, and directed to throw up a small dam on top or in front of the main embankment; its height being about 3 feet; and the contents of the task from 300 to 500 cubic feet. As a rule the able-bodied men got their families to assist them, and the required work was performed in 3 or 4 days cheerfully and satisfactori-

Difficiencies in the embankment made good.

ly. The persons engaged took an interest in the task, and as everybody shared in the labor, it proved neither irksome or degrading to them.

Watchman called out.

213. The agriculturalists had to furnish contingents for watching the embankment, and supplied 3 men per mile for only two or three weeks. From 40 to 60 men were also engaged regularly on the 42nd and on the 58th miles. The rates of pay given were 8 annas per day; or if task work, 10 or 12 annas per 100 cubic feet, these being the usual market rates. The embankments were thus brought up to the requisite height along the entire line, and a guard of 6 men per mile was laid out to keep the grass down and repair leaks. The engineer establishment consisted of four superior officers and three sub-officers arranged in three separate charges along 70 miles of the Nawoon embankment.

Progress of the flood wave.

214. To show the progress of the first flood wave the height of the river surface relative to 1877 flood level, the following table is drawn up, all figures without a sign meaning feet below it, while the plus sign at Mageelaha signifies above it:—

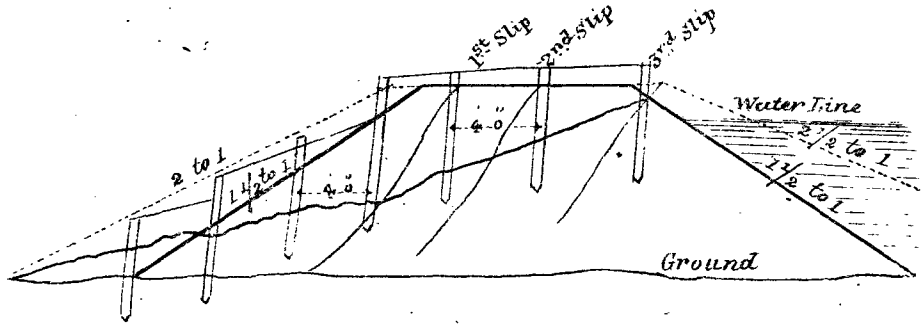
Table 52.

Date.	Thayetmyo.	Myanoung.	Nawoon.	Myogwin.	Laymyetna.	Zimbyogong.	Ngathaingyoung.	Mageelaha.	Zeebingwin.	Taboo.
July 24th... ...	6·12	3·21	2·82	2·83	2·67	3·08	2·08	1·83	0·96	2·92
„ 25th... ...	5·10	2·75	2·69	2·75	2·58	3·04	2·04	1·79	0·96	2·92
„ 26th... ...	4·08	2·38	2·48	2·63	2·58	3·00	2·08	1·74	0·91	2·92
„ 27th... ...	3·21	1·96	2·36	2·54	2·50	2·92	1·95	1·66	0·87	2·84
„ 28th... ...	2·67	1·42	2·15	2·38	2·50	2·83	2·00	1·58	0·83	2·75
„ 29th... ...	2·17	1·13	1·94	2·24	2·46	2·75	1·91	1·46	0·75	2·75
„ 30th... ...	1·88	0·79	1·69	2·06	2·37	2·58	1·75	1·12	0·58	1·59
„ 31st	2·00	0·71	1·36	1·78	2·00	2·38	1·58	0·96	0·50	2·45
„ 1st	2·50	0·71	1·11	1·61	1·75	2·17	1·41	0·60	0·41	2·42
„ 2nd	3·33	0·88	0·98	1·48	1·58	1·83	1·11	0·33	0·25	2·34
„ 3rd	3·50	1·13	0·90	1·39	1·37	1·67	0·75	+0·04	0·04	2·25
„ 4th	...	1·67	0·98	1·36	1·25	1·42	0·41	+0·54	+0·25	2·00
„ 5th	...	2·54	1·23	1·44	1·17	1·23	0·08	+0·88	+0·50	1·75
„ 6th	...	3·38	1·65	1·76	1·29	1·33	0·08	+1·04	+0·67	1·59
„ 7th	...	4·21	2·07	2·06	1·42	1·42	0·00	+1·17	+0·79	1·42
„ 8th	...	...	2·52	2·51	1·47	1·58	0·04	+1·07	+0·88	1·25

Dangerous condition of the embankment.

215. The flood wave of which news were daily received from Thayetmyo and Myanoung seemed so unduly long in showing itself on the Nawoon, that it was thought that it might pass without any great development. A small breach was reported on the lower end of the Myanoung Embankment, and the writer had to examine the Irrawaddy branch of Henzada Embankment towards the beginning of August, when the wave crest was passing down. It had gone through the upper delta, and the Irrawaddy was steadily falling, when a telegram was received from Ngathaingyoung on the 5th saying that 600 feet of the 58th mile had slipped; and the work was in great danger. This was followed by other telegrams, representing the slip as extending at both ends, and other smaller slips appearing elsewere, the writer proceeded to that part threatened. The danger was extreme on the 6th and 7th when the

river was at its highest. The slips were caused by the water soaking through the embankment, which was here of moderately strong clayey loam, but which was neither impermeable nor of sufficient mass to hinder the seepage. The inner slope separated from the main body of the embankment in the first place, and slid down, a soft clayey mass, on the ground below. Further slices continued to leave the body; and in one part little more than the front slope of the work was left intact. As the work stood barely 3 feet above the 1877 flood mark, and the 1879 flood rose about 14 inches above this, while the work was far from being of the proper strength with slopes of 2½ to 1 outside and 2 to 1 inside, little was left to withstand the pressure of the water. Mr. Henry, who was in charge, had been most assiduous, and was thoroughly successful in preventing a total failure; and as the method employed is that which is usual on these works, and has before been successful, a detailed description may be useful. The embankment as it ought to be is shown in dotted lines. The height of the work is about 10 feet. The water rose over 8 feet against it. The continuous straight lines show the work as it had to remain owing to deficiency of funds allotted in suitable time for its strengthening. It was about 11 feet wide at top, with slopes of about 1½ to 1 on each side. The thicker uneven lines show the form the earth assumed after three successive slips, the lines of which are shown. As quickly as possible light piles and posts were driven in the side of the embankment and in the ground, parallel to the crest, and about 4 feet apart, and spilt bamboos were woven, on the spot, to make continuous walling, while fresh clayey earth was thrown in between and puddled by men's feet. The crest was thus maintained above water even where it had sunk below it. The main body was restored to shape, and the inner slope assumed more of the form it ought to have had. If it were not witnessed it could hardly be conceived that the work when so far gone could be restored and made safe, while the great pressure continued, and it was only that abundant materials were at hand, and that the provisions of the Act were freely put in force that disaster was averted. The civil and police officers lent cordial aid, and the people, when the imminence of the danger was so clear, were cheerful and zealous. The whole of the requisitioning for them was done through the civil authorities, and, as far as possible, the men were varied from day to day, so as to permit each person to have as much time to himself as possible. From five to eight hundred persons were called out daily; but some thousands were employed in turn on the different slips. The bill for paying them, which was also done through the Civil Officers, came to Rs. 6,783, which implies 13,566 days labour at 8 annas per day.



Total damage to the works.

216. There were altogether 205 slips on the last 26 miles of the Nawoon Embankment; but none brought great danger except that on the 58th mile, which reached a total length of 1,650 feet. If these slips do not actually cause a breach they do more good than harm, as the process brings about, in clayey loam, a natural puddling of the work; and, when this is made up to the full strength, there can be no possible ground for fear on any place where it has once slipped. Several old slips on other parts now form the strongest portions of the work.

Satisfactory results now attained.

217. That the embankment, notwithstanding its deficiencies, actually resisted the great strain of a rise 14 inches higher than ever before known, must be looked upon as most satisfactory; and had the entire strengthening work been completed the writer believes no such danger as that reported would have happened. But as a re-

petition of the 1877 flood must undoubtedly bring with it a further elevation of at least one foot throughout, the work, in order to be fully prepared for this contingency should be raised a little higher than before designed. At the 47th mile the 1877 and 1879 floods marked the same height. At Mageelaha the latter was about 14 inches the higher. At Zeebingwin it was 9 or 10 inches higher. It is now proposed to raise the height of the work to 3 feet uniformly, from the 47th mile to the end, above the 1879 flood level. An estimate has been made out and sent in for this. The cost of the earthwork will be Rs. 27,000; or with establishment charges, Rs. 38,840. It will be better to incur this expense at once, notwitstanding the improbability of a repetition of the 1877 flood, than to run the risk of damage to the country, besides spending a similar amount in closing breaches as well as having ultimately to carry out this work. The money still available for the works will place them in a thoroughly safe condition for all floods lower than the 1877 one; and when the working season opens in November all that remains to be done will be finished (1).

Further raising required 47th—70th miles.

218. A portion of the 6th mile of the Nawoon embankment runs over a layer of sand; and though the depth of water stands only from 4 to 6 feet incessant trouble has been caused in the 1875, 1877 and 1879 floods by leaks and threatened breaches in this part. One occurred there in 1877 occasioned by the ground being cut from under the work. The cost of repairs to this breach was no less than Rs. 3,826; and a very heavy bill has been incurred during the present year in preventing other breaches. Two courses of remedy are open; one of which is, to take a new line entirely for this length of work over thoroughly good ground, at a cost of 7,000 or 8,000 Rupees; or to excavate a trench in the ground 4 or 5 feet deep and 2 feet wide along the toe of the work; fill it with puddle carried to 2 feet above ground, and then to throw over this a very broad slope of earth with inclination of 4 to 1 or 5 to 1 on the outside. This is the only remedy if the present line is retained. A careful examination will be made of this when the ground is dry (2).

Deficiencies remaining in the work.

219. When the proposals now made are carried out, the Nawoon Embankment will be in safe condition and in good working order. There will be a reasonable assurance of its power of sustaining the very highest flood pressure, and the cost for supervision and maintenance can be very much reduced. This is, at present, 300 Rupees per mile yearly; and by lessening the sum to Rs. 150 per mile or less, as has been done on the older and consolidated works, a saving of Rs. 10,000 or more will be made annually on the 70 miles now existing

Savings to be effected in maintenance.

220. But the work itself will remain incomplete until it is terminated in a satisfactory manner, so as to give the greatest results of which it is capable. In flood at present, the water gets round the end of the work, and between the 70th mile and the two miles of unfinished and disconnected work beyond this. A very small gap exists here, which will be filled during the ensuing season from the money now available. Seven miles will then remain to be done to carry the work as far as the Taboo choung; and these will cost about Rs. 40,000. The completion of this can cause no further change to the condition of the river channel, which is broad and deep and of great capacity in this part. Any effect it can have must be entirely beneficial, by lowering the outfall some 2 or 3 feet, and thus reducing the height to which the inundation penetrates through the Taboo choung. It is therefore strongly recommended that sanction be accorded to carry this work to completion at once.

Extensions necessary to complete the Nawoon Embankment.

221. Designs and estimates have been taken out and will be sent in, in a separate form, for continuing the embankment according to the original plan as far as the mouth of the Daga. This will cross the Shoaynyoungbin choung at the

The Shoaynyoungbin section.

(1).—These works have been sanctioned and will be completed before the 1880 flood rises.

(2).—This Puddling work has also been completed wherever the ground leaked under the embankment (March 1880.)

village of that name, seven miles from Taboo. The cost of these miles is, for work Rs. 60,000, and with establishment to be added on Rs. 75,000. From Shoaynyoungbin to the Daga the length is almost exactly 13 miles; the line passing in one or two places over high ground. The cost of this portion, for works and establishment, will be Rs. 1,10,000; or in all for 20 miles, Rs. 1,85,000.

The Taboo and Shoayngyoungbin choung.

222. Some diversity of opinion has existed as to the best method of dealing with the Taboo and Shoaynyoungbin choungs. The former of these varies from 160 to 200 feet in width near its mouth and has a dry weather depth of over 20 feet at low water. The Shoaynyoungbin varies from 160 to 300 feet wide, and, possibly owing to greater tidal scour, has a slightly greater depth. There would be no serious difficulty in stopping both these creeks by earthen dams, although the work would be heavy and each must cost from Rs. 10,000 to Rs. 15,000. If this were completed satisfactorily and the embankment made continuous to the Daga, the drainage out-fall for the Henzada Plain would on the Nawoon side be lowered to a high flood height of from 8 to 10 feet above mean sea level. At present it is about 15 feet above that level; and as the country hereabouts is exceedingly flat, an immense additional area would be thus reclaimed.

Value of these large streams.

223. But both the Taboo and Shoaynyoungbin make splendid navigable channels and drainage waterways. They are old branches of the Nawoon; and, formerly, doubtless served to carry large bodies of the Irrawaddy water to it. They reach, with much diminished section, to nearly behind Ngathaingyoung, and conduct large boats of forty to fifty tons far into the interior. As drainage channels it is certain that at present they do more harm than good; as, during the higher floods, they pour immense bodies of water into the lower lying plains. The Taboo floods large tracts 20 to 30 miles north of its mouth. Most likely the Shoaynyoungbin does the same. When the Nawoon is lower they carry off the natural drainage due to the rainfall in the interior. Both creeks are thus of undeniable service; in high floods for navigation, at other times for drainage; while they are both injurious to the country in the high floods as sources of inundation. It is thus a question whether they can be retained as navigable and drainage channels and their injurious effects removed or diminished during floods.

The Taboo dam and canal.

224. The writer proposes to close the Taboo permanently with a dam of earth well protected by strong sheet piling from percolation beneath, and to form part of the line of the embankment. This would throw the outfall level to Shoaynyoungbin, lowering it by $1\frac{1}{4}$ feet. There is, at present, a small creek about 40 feet wide and 15 deep, which leaves the Taboo about 4 miles from its mouth to make a short cut across to the other creek at its nearest point $1\frac{1}{4}$ miles off. There are also other creeks at higher points which connect the two principal streams; but they are all like the first mentioned, somewhat tortuous and narrow, being obstructed with trees and roots, and only permitting medium sized boats to pass in the dry season at high tide. It is just possible that these creeks would be ample for drainage purposes, and would conduct the rainfall from the 200 to 300 square miles of plain country from the Taboo to the Shoaynyoungbin; but none is suited for maintaining the traffic by navigation, which is likely to increase with the spread of cultivation. It is therefore proposed to cut an entirely new canal across the narrow neck of land close to the small creek mentioned; and to maintain it at a sufficient depth to permit boats drawing six feet of water to pass at all times of the tide. Detailed plans and estimates are sent in separately for this work, which is shown in Plate XXII. Its length is 1 mile 1,263 feet and cost Rs. 23,320; which, with that of the dam, Rs. 9,646, brings up the total for the first part of the Shoaynyoungbin Section of embankment to about Rs. 33,000.

225. The consideration of closing the Shoaynyoungbin choung itself, and perhaps the question of constructing the second part of this section, should be deferred for some seasons after the first part is complete and the canal is in thorough working order. Little or no change upon the Nawoon River can be produced by these works, but a very considerable improvement will be effected on the country. Comparatively little additional protection can be afforded by closing the Shoaynyoungbin, as there is barely one foot difference between the flood heights at this place and at the mouth of the Daga. This little may ultimately be found sufficient to justify the expense of the additional works necessary to complete the protective measures and at the same time to keep open the navigation; but this can only be decided by the Revenue Officers after further careful examination of the country. In any case the navigation must not be sacrificed; and, if necessary, a canal must be cut from the Shoaynyoungbin to the Daga to keep this open. Examinations and surveys have been made over the whole of this country under the writer's direction, and a series of creeks and waterways have been found which might prove sufficient for the drainage of the interior; but the magnificient natural channels should be preserved and improved rather than obstructed; and if it ever be decided to close the Shoaynyoungbin and carry the embankment to the Daga the canal must be made. The canal will be slightly larger than the Taboo canal, and should follow the line marked down on the map. Its length will be 6 miles, and cost Rs. 1,50,000. No plan or estimate in detail has been prepared, as there is no probability of the work being required for a long time. In both cases the canal and dam should practically form one work, the spare earth from the excavation being taken in lighters to form the lower part of the dam.

The Shoaynyoungbin dam and canal.

226. These interests of navigation within the Henzada Plain, and connecting its interior channels with the surrounding rivers, are only second in importance to the work of reclamation and protection from floods. A network of capacious natural channels reaches all over the plain from the extreme north near Henzada, to Pantanaw and to Shoayloung on the one side, and to Taboo, Shoaynyoungbin and to the Daga on the other. The last named river is itself the most important member of the system. It starts as a creek about 30 feet wide from about the 2½ mile of the Nawoon embankment, and, rapidly enlarging, is soon found as a broad and deep channel increasing from 100 to 400 feet and more wide, and permitting boats to come up from Bassein to Kyonpyau and Pandaw and to opposite Henzada even in the dryest season. A second large river of similar size and capacity, which also permits boats of a few tons burden to pass up to behind Henzada is the Baudee River, which debouches at Baudee opposite Pantanaw. The two larger rivers are connected by several cross creeks in the rains, but these are impracticable in the dry weather.

The interior navigation of the Henzada Plain. The Daga and Baudee Rivers.

227. The most important of the cross creeks which it has been desired to open for permanent navigation is the Wetchoung, which runs from the Daga at a village of that name to the Engma choung, a moderate sized stream opening out past the village of Pathay to the Baudee. The writer examined the water line in February 1877, the water being then very low. The creeks near the Baudee are broad and deep, but on leaving the main stream this water gradually shallows, but the tidal flow permits large boats to get up the Engma and the Mawaybin choungs for a considerable distance. The connecting link, called the Wet choung, is, however, a comparitively small stream from 40 to 70 feet wide, and though deep enough to hold some of the higher tidal water in the dry season, is overgrown with jungle and forest trees, which effectually prevent all passage by boats. As the creek is also tortuous, it cannot lend itself to navigation purposes on a large scale.

Cross creeks and navigation.

228. During high water this route opens a short communication from Rangoon, Yandoon and Pantanaw to Ngathaingyoung and the interior towns to the north; and *via* the Daga, to Bassein in the south. If some of the sinuosities of the larger streams were improved, and a canal cut between the Daga and the Mwaybin to supersede the Wet-choung, a short and safe route, avoiding all the sinuosities and dangers of the present steamer channel in the Delta to the south would be open during six months of the year for steamers between Rangoon and Bassein. But the canal would be very expensive, costing, with the other improvements, not less than 2½ to 3 lacs of Rupees (£ 25,000) (£ 30,000) and it is doubtful whether steamers drawing more than 3 feet of water could pass at all times down the Daga, without waiting for the tide at certain points. To slow boat traffic the delay is of little importance; but it would detract much from the value of this route for steamers. Much may be done to improve the line of communication for boats during high water by clearing the present creeks of trees, and the result will be of great value at present, and greater in the future to the localities accessible by the Daga. The heavier work of a canal is not recommended until the local interests are of sufficient value to justify the expenditure.

Route from Pantanaw to Ngathaingyoung.

229. The remarks now made will suffice to direct attention to the absolute necessity of keeping the Baudee channel entrance always open as a navigation channel; or, at least, of closing it if ever it is closed, by gates and and a lock sufficient to permit the largest vessels ever likely to use this route to pass through at high floods. It has been proposed, and the writer supports the proposal, to continue the Irrawaddy Branch of the Henzada Embankment as far south as Shwayloung. This, by lowering the out-fall, will secure an enormous reclamation at a comparatively small cost, and will be an appropriate termination to the larger embankment on this side of the river. The writer has ascertained, on the spot, that there are sufficient water-ways connected both with the Daga and with the Baudee to ensure a thorough drainage at all times of the interior space. Broad and deep creeks from 150 to 300 feet wide and with clear water pouring into the muddy stream of the Irrawaddy at flood emerge at different points. One of these runs parallel with the proposed embankment from Baudee to Kengwa, just above Shwayloung, which would be ample on this side for drainage. But it will be of no use throwing up the proposed embankment unless the Baudee entrance is closed when the outer floods are higher than the interior waters. Nor will the full benefit from existing works, nor from the last section on this side, to be constructed from Donabyoo to Baudee, be obtained, until the flood water be entirely shut out from this entrance. The Shwayloung extension, while it is necessary for the proper completion of the Henzada Embankment, thus involves the somewhat heavy work of closing the Baudee entrance with moveable gates or a caisson during high floods, and also entails an expensive lock which will permit the passage of steamers through in these floods. While the nature of the work required is now pointed out, it is thought that there is so little prospect of it being carried out for a long time that it is unnecessary to go into details of the works or of the cost.

The Baudee River and the Shwayloung Section of embankment.

230. The Baudee and the Daga must always remain the principal or the only entrances for the interior service of navigation to the Henzada Plain. Nothing has ever been done to improve them in any part of their courses. The Daga is tolerably straight from its mouth to Kyonepyau, and offers an excellent channel with high clear banks, and, generally, with a good depth of water, moved in its lower parts by the tide. But there are a few bars which could easily be removed by a dredger; and, on these being cleared away, a great improvement would result. Above Kyonepyau the river course is very circuitous. Possibly some day it will pay to make cut-offs, but the country is not rich enough to require this at present. It would, however, be a great improvement to introduce a larger

Improvement of the interior streams.

supply of water to the river in the rains. The construction of the embankment has cut off all the sources through the old creeks, and the water level is lowered throughout the whole area of the upper Henzada Plain from 16 to 20 feet. And the old interior chanuels are so large that the rainfall produces a very slight current even with the lowered surface. The smaller creeks through which the water used to come are nearly stagnant, and have barely enough water to float the smallest boats. At present the people use them by dragging boats over a kind of portage, as well as their supplies of timber and bamboos for the interior towns. It would be a great boon to the whole of the interior population, and at the same time an immense improvement to the streams if lock openings could be made from the Nawoon on the one side and from the Irrawaddy on the other to allow the passage of water and boats from these rivers in the rains. It would be somewhat dangerous to leave a free opening, however well protected by masonry, through the embankment to permit a continuous inflow. In high floods the fall from the river to the interior would be so rapid that the current would be excessive and risk would be run of excavating the ground and undermining the works. Were it not for this the writer would recommend the experiment of one free opening just above Ngathaingyoung; the ends of the embankment to be well contained by masonry walls, with invert arches. This is the one where the want of communication and ingress is most urgently felt. Another is at the 3rd and another at the 19th mile of the Nawoon embankment; while at three points on the Irrawaddy side, the 2nd, the 16th and the 45th miles it is most desirable that communication be made between the river and old inlet channels now choked with weeds. Failing the free opening, locks and sluices must be used. Just at present an ordinary iron sluice with 22 inch pipes is being provided for the Ngathaingyoung stream, called the Kyun-choung. Other sluices to maintain a continuous flow of water to the interior, and also syphons, can be applied at numerous places where they will be useful both for irrigation, if needed, and for feeding the streams. But ultimately regular locks will be found the most suitable means of supplying the growing wants of the interior; and these will, in all probability, be first needed at the six points indicated. Much consideration and consultation must precede the designing of these; as from their nature they are expensive, and so much depends on the character of the traffic to be looked forward to for the size of the lock that it is useless taking out details for these until the revenue authorities decide, firstly, that they are wanted, and secondly, what sized boats should be provided for. When authoritative indications are received on these points, the engineering details can readily be furnished. It may in the meantime be assumed that each cast iron sluice and set of piles will cost nearly 2,000 Rs. when fixed. If locks of 100 feet long by 20 feet wide interior dimensions, with 8 feet lift, and provision above the upper sill for a variation of level on the water up to 12 feet be required, these cannot be completed in masonry under Rs. 40,000 to 50,000. They would permit ingress to the interior for the largest native boats at all stages of the river above 30 feet on the gauges.

Further supplies of water.

Portages.

Free opening.

231. Communication by road in the interior is restricted at present to the most nominal amount. Several crude attempts have been made to initiate the development of the interior by roads; but from want of funds sufficient to construct really good roads very little has been done and most of the money spent has been wasted. The only roads that are of the slightest service at present are two constructed by the Deputy Commissioner of Henzada from this town; one to Natmau, 5 miles off, half of which has been metalled; and the other to Dooya 6 miles off, only 2 miles of which are metalled. Another nominal road has been thrown up by the writer and lightly bridged from Ngathaingyoung, past Pandau to Kyonepyau; but as this is only a small embankment six to eight feet wide on top and unmetalled, it is useless except for foot traffic. Other lines of earthen road have been thrown up near Henzada, where marked on the map, but from defects in construction originally, and through never having been kept up, they

Road communication.

are now impassable; and only destroy good paddy land. A connecting road between Henzada and Ngathaingyoung has long been desired and the line as surveyed is marked out on the map. This road, with those already commenced, and others from Henzada to Leymethna by Engabo; from Kyonepyau to Donabyo, from Donabyo to Shwayhlay &c., would open up the principal highways, and be of incalculable benefit to the people. At the present time no cart traffic exists in the whole of this immense plain from June to December in each year. Except on the Natmau, Dooya and Kyonepyau roads it is impossible for a rider to penetrate any part of the district during the rainy season. Communication is only possible, except for foot passengers, along the waterways; and it is with the greatest difficulty that any merchandise or garden produce can now reach or be brought from any place away from these lines except in the dry weather.

Cost of roads.

232. Cultivation has been spreading at a rapid rate and a large and increasing revenue has been gathered for many years from this tract, and, practically, nothing has been done to improve it. It is not from want of devising roads, as the ones mentioned above have long been laid out; it is the simple want of adequate funds being furnished. And unless sufficient funds are furnished each season to make a short length of road quite complete, it will be better to do nothing, as incomplete roads are an obstruction and source of annoyance to everybody. It is barely possible to finish a useful road 20 feet wide, metalled and bridged (excluding the larger bridges) under Rs. 10,000 per mile, in these plains, and any sum short of that will prove injurious rather than beneficial. A 14 foot road may be made for Rs. 7,000 per mile. But sums of Rs. 10,000, 15,000, and 30,000 have been allotted, and attempts have been made to open roads of 10, 15 and 20 miles in length out of them; and these, instead of being maintained at a cost, which long experience proves necessary, of from 100 Rs. to 300 Rs. per mile per annum, have been left without further care to encumber the ground in irregular mud heaps, which prove snares to those beguiled upon them.

Bridges for the navigable streams.

233. Bridges also have been built in connexion with the other lines of road, some of which were well designed to obstruct navigation. Fortunately they were constructed of junglewood which rots in a year or two, so that passages for boats were soon opened. The writer has been called upon to replace two of these built seven or eight years ago; one of which had to be removed in three years. It is indispensable that, first of all, the boat traffic of these large navigable channels shall remain uninterrupted, even to the north of Henzada. Without this the district is sealed for six months of the year. However rude the bridges may be in design or in construction, and, for a long time to come, economy must be the first requisite to be considered, provision must be made for boats passing at all times. The magnificent ironwood of the Burmese hills furnishes posts and girders 40 to 50 feet long, which permit simple structures of small spans of 15 to 30 feet to be easily and strongly made. But a difficulty arises with the crossings of the largest streams of the Daga and the Baudee, where these have depths of water of 30 feet in the dry weather; as to provide room for the high sterned Burmese boats a headway of 12 to 15 feet at least must be allowed, as well as the rise from low to high water. It is suggested that, as this height entails comparatively expensive piers of built up work, a moveable space of 30 feet wide be provided for all bridges over these principal waterways. This would permit a lower roadway, and a simpler and cheaper style of bridge. The designs should be made uniform, as there will be a tendency for the boat traffic to accommodate itself to the requirements and to the facilities offered. Before this uniformity of design can be enforced, it would be desireable to take the opinion of the different authorities concerned, in consultation. No time could be more favorable than the present, when there is a probability of several of these works being commenced, to lay down rules for future guidance. It is

A systematic plan of execution desirable.

likely that within a few years the means of communication will be vastly improved over this area, enhancing both the revenue and the profits to the population.

Inference from experience on the Nawoon to the Irrawaddy.

234. This part of the Report will be fitly closed by the enquiry, how far the results attained on the Nawoon River serve for guidance regarding the proposed double embankments on the Irrawaddy. These results, in this aspect, may be considered under three heads; first, the raising of the water surface; second, the changes in the capacity of the channel hitherto experienced on the Nawoon; third, the changes now in progress, or likely to ensue on this river.

Summary of experiences.

The rise of surface.

235. Under the first head it has been proved by experience that the complete restriction to the river channel in the neighbourhood of Mageelaha of all the spill water formerly lost to the Nawoon over its left bank, of all the immense accession of burden thrown into the river by the development and enlargement of the Thambyading from a small creek with a capacity of not more than 15,000 to 20,000 cubic feet per second, to a size greater than the present trunk of the Nawoon, with a contribution greater than this can carry, and of all the rain water furnished by the local watersheds has not raised the surface of the river more than from 5 to 6 feet. And from the examination of the records of the variations of the river surface during flood it seems certain that this super-elevation would not have been so great were it not for the peculiarly sudden manner in which the spill to the plain on the right rejoins the river above Mageelaha.

The amount of spill and the regular discharge of the river.

236. We have here a river whose channel had attained a tolerably uniform section of about 15,000 square feet, with an average width of 400 to 600 feet, and capacity of 90,000 to 100,000 cubic feet per second, compelled to receive an additional burden of what in the great floods of 1875, 1877 and 1879 must have nearly reached as much more at times. And although the plain reservoir relieved the upper and the mid-trunk in a measure from the immediate effects of this strain, it intensified it in the lower portion of the trunk, from Ngathaingyoung southwards for 20 miles. It is to be regretted that during the present year the exact discharge past Payagyee was not measured at highest flood, as this would have given a definite knowledge of the increase of discharge accompanying the excess rise of 5 feet there; but it was impossible to spare any one from the supervision of the works while the strain was on them. On examining the discharge register for 1878, however, it is found that the river when it stood at the height of 1875 flood, at Payagyee, carried about 112,000 cubic feet per second, the cross-section being a little less than 26,000 square feet; while the 1879 flood stood $5\frac{1}{4}$ feet above this, adding 4,500 square feet to the section, and also increasing the velocity from $4\frac{1}{2}$ to $6\frac{1}{2}$ feet per second at least. The discharge at highest flood could not have been less than 200,000 cubic feet per second.

The changes on the Nawoon in the part.

237. Had the Nawoon been encased with continuous embankments on both sides, it is probable that in the narrower parts of its trunk the rise would have been temporarily greater than 5 or 6 feet. But if the operation had been gradually conducted there is no reason why we should not expect the same enlargement throughout the entire trunk which has been observed in the Thambyading branch. Here the river has been increased from 175 feet in width and 44 feet in depth to 500 feet and 72 feet respectively; the increase of area being from 3,600 to 19,000 square feet in the interval from 1865 to 1877. The whole branch has enlarged proportionately. The mid-trunk in being relieved by the plain from the excess burden has escaped the corresponding enlargement. But there can be little doubt that a similar result would have been attained here had the whole of the water been forced down the soft alluvial

channel. Under the second head we have, then, this enforced enlargement of the Thambyading and of a portion of the upper trunk from Thapangyo to Leymyethna to meet the increased discharge of the river.

The present and future progress of the changes.

238. Under the third head, it is impossible to state with precision what the progress is which is being made in the changes in the régime of the river. The taking of cross-sections at different points, always on the same line, has now been put in hand, and will be continued for some years to learn whether the channel generally is in course of enlargement, and at what rate. During the present year measurements are being made at intervals on cross-sections near to the principal stations. Some of these up to date (September 1879) have been added to the maps. The Thapangyo measuring station has increased to 915 feet in width, and to 30,913 square feet in area up to the 1877 flood mark. One made at Leymyethna on the 8th September shows the area of the cross-section on the same line as that measured in 1878 and 1875 to be now 27,886 square feet; an increase of 2,422 square feet in one year. At Zimbyogong the next lower station the line marked No. 9 in the map which was measured on 18th April 1877, was again measured on 28th August 1879. The width has increased from 488 to 517 feet in width; and the area of cross-section from 15,774 to 20,115 square feet; or by 4,341 square feet during three flood seasons. At Ngathaingyoung, cross-section No. 13 has been measured on 7th June, 13th July and 18th August 1879; its areas to the 1877 flood line being 20,886, 21,915 and 22,554 square feet in area, shewing a decided and continuous increase in size. But no deduction regarding the permanent enlargement of the channel can be drawn from this; as the same section when measured in 1877 had an area of 23,312 square feet; the width of 614 feet being the same (see Plates XXV and XXVI). There have been considerable local changes in the set of the current at this part within the last few years; and a large sand-bank which was formerly above the town has moved steadily down across this particular cross-section, which may perhaps account for the decrease in area since 1877. Further measurements will show the permanent result. At Mageelaha again, three measurements were made on 12th June, 11th July, and 20th August 1879 on the same line. Apparently a decrease in area resulted, as the cross-section had 26,156, 25,002 and 25,336 square feet up to the 1877 flood level at those dates. A change of this kind at short intervals tells little or nothing regarding the history of the river, as changes in the set of the stream cause the position of the moveable lining in the channel to vary. At Zeebingwin the measuring station for discharge had an area up to 1877 flood level of 28,382 square feet on the 7th August 1878. On the 22nd August 1879 the same cross-section measured 29,133 square feet. The difference is too small to infer a permanent enlargement.

Probable results.

239. It is probable, however, that this process of enlargement will be continuous until the whole trunk is large enough to contain the supply furnished to the river, within its banks. The enlargement will progress from above southwards towards Ngathaingyoung, and from Zeebingwin and Mageelaha northwards towards the same place, which will be the last to feet it. But as this progresses the flood surface will be gradually and surely lowered, and the land now swamped in ordinary floods on the margin of the river from Zimbyogong southwards will emerge and be again fit for cultivation. Above this place, hand in hand with the enlargement of the channel of which we possess clear proof, and of the future lowering of the flood level which is equally certain we have another operation tending also to restore the land in the river bank to cultivation. The writer has carefully examined this again lately after the flood of August 1879 and found layers of rich silt deposited all along the river banks from Thambyading southwards as far as Zimbyogong. In many places two or three feet in thickness had been added. The new fields will be much more valuable than the old; and they are certain to be taken up for cultivation again in a year or two.

Compensation by the river.

240. The river is thus rapidly restoring all it has temporarily injured and when its flood surface about Mageelaha is permanently lowered again there will be not only a complete restoration of the original cultivation, but the new system of embankment works will be rendered absolutely safe, affording protection to all the eastern plains, as well as a regularised régime of the river which may permit the western plains to be taken in hand. The disturbance of local interests, which was inevitable from the natural changes, will thus prove a temporary and passing inconvenience, amply compensated in the rich results attained.

Restoration of cultivation.

241. That the disturbance has been and is quite local may be learned from the changes in the high flood water level at Bassein which have been marked by Mr. L. L. Downes in his office there, which is supported by posts standing in the water, and who has kindly kept the writer informed concerning the various flood heights as marked upon the posts. Taking the 1875 flood for comparison, the 1876 flood marked 2 inches higher; the 1877 one 5 inches above that of 1875; the 1878 one the same as in 1876; while the 1879 flood marked ½ inch above the 1877 flood on the 6th August; this being the highest point reached by any flood wave. A telegram has since been received from Mr. Downes, dated 15th September, saying that the water marked on that date ½ inch still higher than the last, or 6 inches in all above the 1875 flood. As no flood wave of great size passed down the Nawoon on this date, the extreme rise recorded could only come from a swell proceeding from the sea. It was not a sudden rise and fall, however, but lasted over one or two days. No sufficient explanation has been received of this strange rise.

Changes in the flood level at Bassein.

242. Turning now to the Irrawaddy, we have a river whose cross-section varies from 250,000 to 150,000 square feet in the main channel, and whose flood channel varies in width from one mile to over five miles. The contemplated addition to its burden in the lower half of its course in the upper delta through restricting its present spill to its channel can rarely if ever reach to one tenth of its daily discharge at any point of this course. And owing to the moderating action of the various reservoirs and channels making up its flood channel, any sharp and sudden accession of daily volume at the head of the delta will be cut down and moderated in the passage of the wave southwards so that the same mass of water must be distributed over a larger and larger number of days flow with a smaller variation of height at the successively lower points of the course. No further disturbing supply of rain except that which falls on the river surface can reach the river in the delta. Here too, the banks on both sides, from Myanoung southwards to the sea are of the softest alluvial deposit, which the river only two easily and readily moves in fractions of square miles at a time.

The Irrawaddy compared with the Nawoon.

243. Everything is then in advantageous contrast to the Nawoon and promises the most favorable result from embanking on both sides. The increase of volume on the large river is disproportionately small when compared with the increase and the regular discharge upon the Nawoon. The great readiness with which the Nawoon upper trunk has yielded to the small excavating power of the water during the last ten or twenty years, is most encouraging in the prospect it affords of a much more rapid corresponding enlargement of the delta channel of the Irrawaddy to accommodate the new burden. The excess of strength residing in the flowing flood mass will thus find useful employment, and it is in the highest degree improbable that the new flood surface due to the double embankments will ever rise so high above present floods, as has been the case on the Nawoon. This is all that can at present be said from the practical experience acquired. There is a total absence in the delta of the Irrawaddy of the circumstances which have intensified the effects on the Nawoon; and while such complete details are wanting as are needed to give precise statements of expected results

Encouraging prospects for double Embankments on the Irrawaddy.

on the Irrawaddy, the whole history of the changes now detailed is such as to give every confidence to the engineer, who, with proper precautions, undertakes the construction of double embankments on that part of the Irrawaddy channel lying between Talokmoh and Yandoon.

Precautions necessary to be observed in constructing them.

244. A statement of the precautions suggested will now be given; but, before this, the expectations formed, which are such as may be reasonably be held, may be detailed. There is every reason to expect that, after a time, the slope of the river surface between Saiktha and Yandoon will approximately coincide after the embankments are constructed with the slope it would assume now at any height of flood. That is, even assuming what is probable, that there would be local elevations of river surface if sudden changes were made in the régime of the river by shutting in large quantities of spill before the channel were enlarged, there would shortly be an enlargement of the section and increase of capacity which would permit the new volume to pass down at the old height without any super-elevation of surface. If a preliminary, or even a progressive and gradual enlargement of the channel could be secured, the spill could be restricted in a measure proportioned to the capacity. There would thus be no danger of a continuous raising of the surface in the lower half of the channel, the apprehension of which is the principal cause of the delay of putting these most important works in hand.

The lower end of the channel should be first enlarged.

245. The precautions to be taken, therefore, consist in trying to secure before-hand, by the excavating power of the water, which has been proved to exist in super-abundance, an enlargement of those lower parts of the channel where the greatest effect of the restriction will be felt. It is obvious from the experience on the Nawoon, and from the records of other rivers when similarly treated, that if the restriction of the spill water to the river and the gradual enlargement of the channel progress from the upper parts downwards the resulting action is much more intensified upon the lower parts than if the entire course of proceeding were reversed, and the enlargement first took place below and gradually proceeded upward in the river channel. If then, by any means, even at the cost of deferring for some years the complete protection of the country to be reclaimed, the progressive enlargement of the lower parts of the channel can be ensured, this is the course which, naturally and scientifically, should be followed.

The creeks on the eastern bank should all be closed as the first step.

246. The first step to be taken with that aim is one first recommended by the writer in his Report dated Prome 11th April 1868. This consists in closing all the creeks running from the Irrawaddy through its eastern bank to the Hline. On analysing the causes of the inundation which lies yearly on both banks of the Hline, and finding that it proceeded from three sources:—the Pegu Yoma torrents; the Irrawaddy flood spill over the banks; and the inflow from the streams now referred to, the Report proceeds:—para 76. "The third source of supply is the Irrawaddy, and that in two ways. One is the spill of the flood waters, which come over the banks in August and September, but the inundation exists when these floods are only trifling; and as the method of dealing with them has already been considered I will assume them disposed of. The other way the water comes in and is from some creeks which run from the Irrawaddy to the Hline. I regret I have not had time personally to examine these creeks or cause them to be measured, but I made enquiries from natives and persons who are well acquainted with them and with the country, and I received the names of 8 of these. Seven of them would average less than a 1000 square feet sectional area each, or on the whole 7000 square feet as a maximum. The Teandau Choung I could not get precise information about, but it is said to have water flowing

Quotation from Report of 1868.

1 Phankabin Choung.
2 Sa-meik-gyee „
3 Ley-eway „
4 Ley-win „
5 Mingyee „
6 Na-bhat „
7 Mo-nyo „
8 Teandau „

through in the dry weather, which would give it a depth of about 34 feet. From the information I received from the Burmese I believe I will be justified in taking its width at 200 feet. This, with a mean depth of 25 feet, gives 5000 square feet, or with the previous ones 12,000 square feet. (77) The water is said to rush through these creeks with great force, which may be well imagined from the fall of the ground to the Hline. If its velocity is taken as before (4 miles per hour) the maximum discharge will be 70,440 cubic feet per second. But this will only take place when the Irrawaddy is at its highest. There will be, however, a constant stream pouring through from July to November; and if we assume that the Hline has just sufficient capacity to do its proper work, the carrying away of the drainage water from the plain and the eastern hills, the water poured in from the Irrawaddy would more than account for the great excess which lies in the form of a lake upon the land for months and renders it incapable of being used. This will readily be understood when it is known that if only two thirds of the maximum discharge of the creeks, or 47,000 cubic feet per second, were to flow constantly for 53 days 14 hours it would fill a lake 110 miles long and 12 miles wide with an equal depth of 6 feet. This is about the amount which by September lies on the Hline, and is slowly drained off afterwards. (78). For at least an entire month, and for some times six weeks in the year, these creeks are full to their banks, and discharge all they are capable of. If, then, they were stopped, and this water shut off, a great effect would be produced. The Hline may be quite capable of carrying off the water from the other sources, and, if so, 840 square miles would be reclaimed (exclusive of the 560 of scheme No. I). If the depth of water were reduced only six feet, all the higher land would appear, and a margin about a mile broad on both sides of the Hline, or over 200 miles in all would be saved. The actual results it is impossible to predict, but I am sanguine that the benefit would be immense. (81) I would beg permission to recommend that the stopping of these creeks be carried out at once, separately from the general scheme and preliminary to it."

Quotation from Report of 1810.

247. The purpose contemplated when these proposals were made was less the effect on the Irrawaddy River than the reclamation of the low land of the Hline Valley. In the writer's Report dated 6th July 1870 the proposal was repeated as follows:— para 70 "There is a method by which some of the advantages to be obtained by embanking both sides of the river may be at once reaped with little risk and trifling expense. The greater portion of the damage done is due to the streams which run from the Irrawaddy to the Hline. The water fills the whole of the low ground before the floods top the bank, and even in those years when they do not rise to the edge of the bank. It is clear that, if all the streams were stopped up, the only evil would be caused by the floods; and if these do not rise over the banks more than once in three years the ground might be cultivated twice out of the three years. In any case, as the channel of the Hline would be comparatively free, it would carry off the flood water as fast it came over the banks, and thus the whole of that strip of land to the east of the Hline now annually inundated, would be effectually reclaimed. The area of this would be nearly 300 square miles. The water now discharged by these creeks would be thrown into the Irrawaddy, so that the effect would be on a small scale, what completely embanking both sides would be on a large scale. But it is to be observed of these streams that, although they discharge an immense quantity of water from the Irrawaddy when it is rising; at full flood their velocity is checked, as the area of the low ground is filled. I caused assistants to measure the discharge of the Teandau creek during the greatest flood of 1869. The average velocity was only about two feet per second. A short time afterwards I visited it, and found the velocity still very slow. The waters continued falling in the Irrawaddy; and soon after my visit the Assistant Commissioner of Tharrawaddy found the water flowing into the Irrawaddy as he came in a boat from the Hline (1.) Thus the effect of the stream

(1) This is an error; as the water from the Hline never flows into the Irrawaddy; but at high flood the part of the Teandau choung nearest the Irrawaddy receives a large body of water from a minor channel passing Monyo; and this flows back into the Irrawaddy, while the eastern half of the creek has its current running into the Hline.

which is the only one of importance, is trifling in relieving the Irrawaddy at full flood, the only time when it is desirable to do so. And by observing the actual effect of this operation on the river channel, a great step will be made towards solving the greater problem of embanking both sides. It is quite certain that if these streams cannot be closed with safety, no attempt whatever can be made to shut in a much large quantity of water. Precaution can be taken so as to ensure the removal of the dam at a few hours notice, should the action on the river in the lower parts be considered dangerous ; while, if successful, the certain reclamation of 300 square miles, and the possible practical cultivation of nearly 900 more will be the reward of the attempt. The cost of the works required should not be more than 30 or 40,000 Rs. If the suggestion, in its present form, is approved, definite plans and estimates will be made out after exact measurements of the requirements are taken.

Removal of recommendation to close the eastern creeks.

248. Here the second result of closing these creeks, the action on the Irrawaddy channel, is adverted to, and the writer has now only to renew the recommendations there given. There will be for all stages up to high flood, from that stage when these creeks begin to flow, which is somewhat less than half flood, a raising of the surface of the river in the lower half of the channel as a first consequence of shutting in the water that now escapes by them. The channel will thus be called upon to permanently perform a larger amount of work than before, in passing the increased burden. There will be a continual and progressive excavation of the lower half of the channel corresponding with this ; and which our experience on the Nawoon makes it absolutely certain must ensue. No possible harm can in the meantime result from this to the country, which will be protected from inundation at all stages below high flood ; and the lower plains will then be free to receive and store up such spill water as may reach them at highest flood ; possibly without ever permitting the higher strips of ground, which measure some 300 square miles in the Hline valley, to be submerged. It is now proposed to close not only the creeks above mentioned north of the Teandau ; but all the others from Teandau southward to Yandoon. We possess accurate measurements of the whole, and detailed estimates can be readily submitted of the cost of closing them ; but, at present, a re-assertion of the principle is all that is desired, with a view to obtaining orders on this point, if it is considered expedient to continue the measures of reclamation.

Further recommendation to embank the lower portion of the channel first.

249. With the same end in view of first enlarging the lower half of the channel of the upper delta of the Irrawaddy before carrying out a systematic protection of both banks it is suggested that the ordinary course of commencing the double embankments at the upper end of the channel and continuing them southward be reversed. At present, owing to the lowering of the river surface to the south of the Thambyading bend, cultivation has extended and flourishes all along the left bank from Sarawa southwards on a margin sometimes reaching nearly a mile in width. When the inevitable cut-off takes place, a considerable portion of this will be injured, if not the whole, and it is possible that while there may be a resumption of cultivation on the same margin to the north of the bend (which for the last ten years has been entirely uncultivable), all to the south may be ruined even in ordinary high floods. The writer would therefore strongly recommend that, after the present Henzada embankment on the Irrawaddy side has been raised and strengthened to meet the anticipated raising of the river surface, as described in Part III, a light embankment kept every where two feet lower in its crests than the Henzada embankment, should be carried from Sarawa to Yandoon, throughout the length of the lower half of the channel referred to. This will, in all probability, suffice in ordinary high floods of the Irrawaddy to give protection to the existing cultivation, and probably permit, with the closing of the creeks, a further extension. It will, at the same time, assist materially in the excavation and enlargement of the lower half of the chan-

nel, by keeping for a longer period a larger body of water in it. A double purpose will thus be served. The object of keeping it lower and weaker than the embankment on the right bank is, to permit it to be easily breached when any extreme high flood brings a strain on both works. It is important in such a case to preserve the Henzada plain in preference to the other side; as here, cultivation is extending rapidly; and there is a tacit understanding that every endeavour will be made to afford permanent protection where reasonably practicable. On the other side no protection is yet afforded or promised; and it is only fair that, in a course of tentative proceedings such as are now contemplated, the exact nature of what is offered should be made known to the cultivators. Certain cultivation exists and will shortly need protection. It is inexpedient to attempt general or permanent protection at first, and only partial protection can be offered. This can be made in the interests of those already residing there, and will also be made with the view of improving the river. But a rapid extension of cultivation is very probable even with inefficient protection, and the native revenue officers should instruct the cultivators that in extreme high floods they run considerable risk of their crops being injured. No loss of life or serious damage to property need ever be apprehended from the floods in the Irrawaddy Delta.

250. In conluding the writer would seriously urge the necessity of continuing with a trained and efficient staff the studies on the river and on all subjcets connected with its improvement which have been commenced or are still wanting. However crude may be the data or the reasonings contained in the present Report, and however imperfect the conclusions, they will not be without value if they lead to a persistent effort to gather and place on record the minutest details on all points which can bear upon or relate to the river, its past and present changes, and the improvement and development of its channel, its riverain plains and delta, or its gathering grounds. The only merit claimed for the present attempt is, that all the data that it has been possible to gather have been brought together and arranged; and, it is thought, no deductions or practical applications have been made which were not fully justified.

The studies commenced in this Report should be continued.

ROBERT GORDON,

Embankment Officer,
Irrawaddy Embankment Works.

HENZADA:
3rd October 1879.

Appendix No. I.

ACT NO. 13 OF 1877.

An Act to provide for the execution of works urgently required in connection with embankments in British Burma.

Preamble.

Whereas it is expedient to provide for the execution of works urgently required in connection with embankments in British Burma; it is hereby enacted as follows :—

Short Title.

1. This Act may be called.—"The Burma Embankment Act 1877." It extends to all the territories for the time being under the administration of the Chief Commissioner of British Burma.

Commencement Interpretation clause.

And it shall come into force on the passing thereof.

Embankment.

2. In this Act—"Embankment" means any embankment constructed for the purpose of excluding, regulating or retaining water, and includes all earthen, walls, dams, canal drains, piers, groins, sluices, buildings, water gauges, bench marks and other works subsidiary to any such embankment and

Embankment Officer.

"Embankment Officer," used with reference to an embankment, means the officer appointed by the Chief Commissioner by notification in the British Burma Gazette, to carry out this Act in respect of such embankment.

Circumstances under which this Act may be put in operation.

3. Whenever the Embankment Officer has reason to believe that unless some works is quickly executed in connection with an embankment, loss of life or extensive damage to property will ensue, and that the labourers or materials required for the execution of such works cannot be obtained in the ordinary course in time to enable him to execute such work with the expedition necessary in order to avert such loss or damage, he may, by order under his hand direct that the provisions of this Act shall be put into operation for the execution of such work; and thereupon :—

Powers to impress labor.

(a.) Every able bodied person who resides in the neighbourhood of such embankment, and whose name appears in the list hereinafter mentioned, shall, if required to do so by such officer or by any person authorized by him in this behalf, be bound to assist in the execution of such work by labouring thereon as such officer or any person authorized by him in this behalf may direct; and

Power to take materials.

(b) such officer or any person authorized by him in this behalf may enter into and upon any immoveable property in the said neighbourhood and take possession of, appropriate and remove any trees or bamboos whether standing or not, and any timber, mats, rope or other materials found in or upon such property, and use the same for the purposes of such work.

List of labourers.

4. Subject to such rules as the local Government may from time to time, with the previous sanction of the Governor-General-in-Council, prescribe in this behalf, the Deputy Commissioner shall prepare a list of the persons liable to be required under section 3 clause (a), to assist as aforesaid, and may from time to time add to or alter such list or any part thereof.

Payment for labour impressed and materials taken.

5. All persons labouring, or detained for the purpose of labouring, in compliance with a requisition made under section 3, or whose materials may be taken under that section, shall, as soon as may be reasonably practicable, be paid by the Embankment Officer for their labor and detention, or for

such materials (as the case may be), at such rates, not being less than the highest market rates for similar labor or materials for the time being prevailing in the said neighbourhood, as the Chief Commissioner may, from time to time, by written order direct.

Compensation for damage done in taking materials.

6. When from the removal of any trees, bamboos or other materials under section three, any damage, over and above the price payable for such materials under section five, results directly to any person the Embankment Officer shall pay to such person such sum as may be agreed upon as compensation for such damage, or in case of dispute as to the amount so to be paid, as the Deputy Commissioner of the district may award, subject to such rules, as to appeal or otherwise, as the Chief Commissioner may from time to time prescribe in this behalf.

Penalties for trespass on embankments, &c. &c.

7. Where an embankment officer has been appointed for any embankment, any person who, without the permission of such officer—

(a.) Grazes any cattle or allows any cattle under his charge to trespass on such embankment, or

(b.) Cuts or roots out any trees, shrubs or grass growing on such ement, or

(c.) Obstructs any drain or sluice connected with such embankment, shall be punished with imprisonment, for a term which may extend to six months, or with fine which may extend to two hundred rupees, or with both.

Explanation.—In this section, clause (a), "cattle" includes also elephants, buffalows, horses, mares, geldings, ponies, colts, fillies, mules, asses, pigs, rams, ewes, sheep, lambs, goats, and kids.

Certain persons to be deemed public servants.

8. Every Embankment Officer and every person authorized by an Embankment Officer to act under section three shall be deemed to be a "public servant" within the meaning of the Indian Penal Code; and nothing in the British Burma Labour Law 1876 section 71, shall apply to any such officer or person acting under section three of this Act.

STATEMENT OF OBJECTS AND REASONS.

The primary object of this bill is to legalize and regulate the levying of labour when sudden danger threatens embankment works in floods, and when such labour cannot be hired. The necessity for provisions of this kind became apparent in the Irrawaddy floods of 1875, when some of the embankments were breached and others overflowed. In some cases the people whose property was threatened with injury came forward cheerfully and prevented further disaster; but in others, where the danger was equally real and of greater extent, but not so immediately apparent, great difficulty was experienced in getting the people whose lives and property were jeopardized to assist in any way in saving the works.

The great losses of life and property that have occurred during the last few years all over the world prove that the works esteemed the most perfect are liable to such sudden and unforeseen failures, and almost universal experience proves that the only remedy possible to apply in such cases consists in the labour of the persons most interested being concentrated on the weaker spots under proper direction.

This Bill will therefore legalize a practice which already obtains imperfectly in Burma, and which is general where embankment works exist.

In drawing up the details of the Bill, attention has been given to Act No. I. of 1858, relating to similar works in Madras.

A. CLARKE.

WHITLEY STOKES,

Secy. to the Govt. of India.

CALCUTTA.

The 12th March 1877.

Appendix II.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Month and Date of Observation.	Number of Floats.	Angle.		Distance reduced from bank.		Time.		Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Remarks and Gauge Reading.
		Upper.	Lower.	Upper.	Lower.	Upper.	Lower.					
		° ″	° ″									
5th August 1878 Surface Velocities.	1	11·43	347·10	46	41	5	2·10	125	200	1·60	A + ½	Gauge Reading 37·73 feet at 7-40 A. M.
	2	13·58	347·30	48	49	11	2·14	123	200	1·62	A	
	3	20·08	340·25	74	72	1	1·53	112	200	1·78	A	
	4	17·14	343·25	62	62	22	2·47	145	200	1·37	A	
	5	25·52	...	...	96	36	2·17	101	200	1·98	A	
	6	24·24	330·40	118	90	48	2·00	72	200	2·77	A	
	7	37·20	328·22	126	152	25	1·15	50	200	4·00	B	
	8	26·27	327·55	134	99	57	1·54	57	200	3·50	A	
	9	41·32	316·30	196	177	33	1·24	51	200	3·92	B	
	10	51·18	307·10	267	249	19	1·10	51	200	3·92	C	
	11	56·58	302·12	322	307	15	1·01	46	200	4·34	C	
	12	59·55	299·40	370	345	13	·56	43	200	4·65	C	
	13	62·48	296·40	422	389	41	1·22	41	200	4·87	C	
	14	64·55	294·55	469	427	0	·44	44	200	4·54	D	
	15	65·53	293·05	473	446	15	·58	43	200	4·65	D	
	16	66·12	293·39	486	453	42	1·25	43	200	4·65	D	
	17	67·10	292·30	507	475	5	·48	43	200	4·65	D	
	18	68·52	290·50	575	517	39	1·19	40	200	5·00	D	
	19	68·14	291·15	527	500	9	·50	41	200	4·87	D	
	20	70·20	289·26	595	559	54	1·36	42	200	4·76	E	
	21	71·18	288·30	634	590	15	·55	40	200	5·00	E	
	22	71·18	288·20	627	590	28	1·08	40	200	5·00	E	
	23	...	...	...	...	41	...	...	...	...	...	Sunken.
	24	73·30	287·50	689	675	41	1·26	45	200	4·44	F	
	25	73·54	286·30	721	692	39	1·25	46	200	4·34	F	
	26	73·50	286·03	699	689	37	1·20	43	200	4·65	F	
	27	74·40	286·02	699	729	35	1·31	56	200	3·57	F	
	28	74·35	285·10	755	725	42	1·41	59	200	3·39	F	
	29	75·34	285·08	753	777	32	1·34	62	200	3·22	F	
	30	75·38	284·01	803	780	54	1·53	59	200	3·39	F	
	31	75·30	284·10	812	773	18	1·28	70	200	2·85	F	
		° ″	° ″									
Surface Velocities taken on the 6th August 1878.	1	21·25	343·52	64	78	22	2·26	124	200	1·61	A	Gauge Reading 37·80 feet at 8 A. M.
	2	14·46	342·22	66	52	29	2·01	92	200	2·17	A	
	3	33·24	329·15	121	131	33	1·35	62	200	3·22	B	
	4	30·50	327·22	131	112	46	1·46	60	200	3·33	B	
	5	31·55	325·27	142	124	52	1·49	57	200	3·50	B	
	6	40·16	321·02	162	169	24	1·21	57	200	3·50	B	
	7	43·38	...	...	190	53	1·43	50	200	4·00	B	
	8	48·37	310·50	245	226	37	1·27	50	200	4·00	C	
	9	50·17	308·20	259	240	31	1·18	47	200	4·25	C	
	10	53·34	305·48	294	271	51	1·38	47	200	4·25	C	
	11	55·04	303·40	315	286	31	1·17	46	200	4·34	C	
	12	57·34	302·20	324	314	7	·52	45	200	4·44	C	
	13	60·36	299·08	362	354	19	1·03	44	200	4·54	C	
	14	63·20	296·21	416	398	50	1·32	42	200	4·76	C	
	15	64·07	295·30	438	412	59	1·11	42	200	4·76	D	
	16	66·01	293·40	486	449	56	1·37	41	200	4·87	D	
	17	67·44	292·20	503	488	35	1·17	42	200	4·76	D	
	18	69·43	290·20	559	541	15	·57	42	200	4·76	D	
	19	69·25	290·00	549	532	54	1·37	43	200	4·65	D	
	20	70·22	289·28	596	560	36	1·18	42	200	4·76	E	
	21	71·07	288·50	647	584	52	1·34	42	200	4·76	E	
	22	71·30	288·28	633	597	28	1·09	41	200	4·87	E	
	23	72·12	287·58	695	622	39	1·20	41	200	4·87	E	
	24	72·26	287·20	668	631	16	·59	43	200	4·65	E	
	25	73·02	286·30	721	655	21	1·04	43	200	4·65	F	
	26	73·33	286·00	698	677	12	·55	43	200	4·65	F	
	27	75·02	284·59	865	748	50	1·38	48	200	4·16	F	
	28	74·55	285·03	749	742	15	1·04	49	200	4·08	F	
	29	75·10	284·38	841	755	24	1·20	56	200	3·57	F	
	30	75·30	284·18	820	773	7	1·07	60	200	3·33	F	

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Month and Date of Observation.	Number of Floats.	Angle. Upper.	Angle. Lower.	Distance reduced from Bank. Upper.	Distance reduced from Bank. Lower.	Time. Upper.	Time. Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Remarks and Gauge Reading.
		° ″	° ″									
Surface Velocities taken on the 7th August 1878.	1	15·40	343·30	63	56	21	1·48	87	200	2·29	A	Gauge Reading 37·80 feet at 7-45 A. M.
	2	26·42	338·07	81	100	36	2·02	86	200	2·32	A	
	3	37·46	323·50	155	154	54	1·50	56	200	3·57	B	
	4	42·26	327·48	135	182	33	1·29	56	200	3·57	B	
	5	33·36	327·00	129	132	43	1·44	61	200	3·27	B	
	6	36·00	322·55	161	145	29	1·30	61	200	3·27	B	
	7	40·02	318·40	184	168	34	1·30	56	200	3·57	B	
	8	47·46	310·45	244	220	57	1·47	50	200	4·00	C	
	9	60·57	299·30	368	360	28	1·12	44	200	4·54	C	
	10	59·42	300·00	346	342	31	1·16	45	200	4·44	C	
	11	59·10	300·40	355	335	24	1·08	44	200	4·54	C	
	12	61·55	298·05	377	374	31	1·14	43	200	4·65	C	
	13	61·35	298·07	378	369	30	1·12	42	200	4·76	C	
	14	61·45	297·50	407	372	8	·50	42	200	4·76	C	
	15	65·50	294·05	450	445	14	·55	41	200	4·87	D	
	16	67·56	292·00	495	493	47	1·27	40	200	5·00	D	
	17	70·02	289·40	603	550	30	1·14	44	200	4·54	D	
	18	70·40	288·50	647	570	38	1·20	42	200	4·76	E	
	19	71·44	...	...	605	53	1·34	41	200	4·87	E	
	20	71·52	288·10	621	610	15	·56	41	200	4·87	E	
	21	71·12	288·40	640	587	39	1·18	39	200	5·12	E	
	22	73·02	286·50	737	655	23	1·06	43	200	4·65	F	
	23	72·30	286·35	725	634	48	1·38	40	200	5·00	E	
	24	72·54	286·50	737	650	35	1·18	43	200	4·65	E	
	25	73·02	286·30	721	655	23	1·04	41	200	4·87	F	
	26	73·52	286·00	698	691	8	·54	46	200	4·34	F	
	27	74·08	285·22	765	703	55	1·42	47	200	4·25	F	
	28	74·40	284·20	822	729	37	1·25	48	200	4·16	F	
	29	75·00	284·50	855	747	43	1·25	42	200	4·76	F	
	30	75·26	284·30	833	769	54	1·48	54	200	3·70	F	
		° ″	° ″									
Velocities taken on the 8th August 1878.	1	17·26	346·15	50	62	3	2·21	138	200	1·45	A	Gauge Reading 37·80 feet at 8 A. M.
	2	16·17	344·50	60	58	34	2·20	106	200	1·88	A	
	3	22·40	339·	76	83	12	1·55	103	200	1·94	A	
	4	23·24	335·40	96	86	57	2·35	98	200	2·04	A	
	5	32·14	326·30	137	126	17	1·16	59	200	3·39	B	
	6	29·48	328·50	129	114	37	1·58	81	200	2·46	B	
	7	37·35	...	...	153	5	1·14	69	200	2·89	B	
	8	38·36	320·30	170	159	59	1·53	54	200	3·70	B	
	9	40·52	317·40	190	172	12	1·05	53	200	3·77	B	
	10	42·55	315·45	205	185	3	·53	50	200	4·00	B	
	11	46·35	313·06	215	211	40	1·30	50	200	4·00	C	
	12	46·54	312·08	223	213	29	1·18	49	200	4·08	C	
	13	49·52	308·20	259	237	45	1·32	47	200	4·25	C	
	14	53·55	305·45	293	274	24	1·11	47	200	4·25	G	
	15	56·34	...	...	302	11	·57	46	200	4·34	C	
	16	58·48	300·08	348	330	44	1·29	45	200	4·44	C	
	17	63·48	296·05	411	406	15	·58	43	200	4·65	D	
	18	64·13	295·05	430	414	39	1·21	42	200	4·76	D	
	19	66·10	293·38	486	452	39	1·22	43	200	4·65	D	
	20	66·35	293·	471	461	33	1·14	41	200	4·87	D	
	21	68·53	291·12	526	517	12	·55	43	200	4·65	D	
	22	70·20	289·21	592	559	49	1·32	43	200	4·65	E	
	23	70·50	289·12	587	575	20	1·01	41	200	4·87	E	
	24	71·33	288·20	627	599	46	1·27	41	200	4·87	E	
	25	72·12	287·23	670	622	8	·49	41	200	4·87	E	
	26	71·55	287·50	689	612	23	1·04	41	200	4·87	E	
	27	72·41	287·18	666	641	7	·48	41	200	4·87	E	
	28	73·16	286·30	721	665	43	1·28	45	200	4·44	F	
	29	74·24	285·25	768	716	40	1·25	45	200	4·44	F	
	30	75·10	284·30	833	755	35	1·27	52	200	3·84	F	

Appendix II.—concluded.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Month and Date of Observation.	Number of Floats.	Angle.		Distance reduced from bank.		Time.		Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Remarks and Gauge Reading.
		Upper.	Lower.	Upper.	Lower.	Upper	Lower.					
		° ″	° ″									
Velocities taken on the 9th August 1878.	1	19·11	340·30	75	69	44	3·10	146	200	1·37	A	Gauge Reading 37·70 feet at 8 A. M.
	2	31·08	328·30	127	120	48	2·09	81	200	2·46	B	
	3	22·15	335·50	96	81	18	1·38	80	200	2·50	A	
	4	24·11	333·25	103	89	11	1·25	74	200	2·70	A	
	5	31·	326·55	139	120	46	1·53	67	200	2·98	B	
	6	39·24	321·10	162	164	8	1·02	54	200	3·70	B	
	7	39·23	319·50	179	164	29	1·24	55	200	3·63	B	
	8	42·16	317·50	192	181	56	1·53	57	200	3·50	B	
	9	44·43	314·45	212	198	33	1·29	56	200	3·57	B	
	10	50·33	308·25	259	243	37	1·25	48	200	4·16	C	
	11	57·50	302·20	324	318	57	1·38	47	200	4·25	C	
	12	62·25	297·37	401	382	17	1·02	45	200	4·44	C	
	13	64·37	295·15	433	421	3	·46	43	200	4·65	D	
	14	65·20	294·28	459	435	6	·49	43	200	4·65	D	
	15	66·38	293·01	471	462	26	1·07	41	200	4·87	D	
	16	66·10	293·46	489	452	27	1·10	43	200	4·65	D	
	17	65·40	293·50	490	442	47	1·28	41	200	4·87	D	
	18	66·54	292·55	518	468	48	1·31	43	200	4·65	D	
	19	68·38	291·10	525	511	30	1·12	42	200	4·76	D	
	20	69·27	290·10	554	533	30	1·12	42	200	4·76	D	
	21	69·45	289·50	609	542	21	1·03	42	200	4·76	D	
	22	70·30	289·19	591	564	19	1·00	41	200	4·87	E	
	23	69·45	289·25	594	542	48	1·25	42	200	4·76	D	
	24	70·24	289·16	589	561	14	·56	42	200	4·76	E	
	25	70·40	288·45	644	570	32	1·14	42	200	4·76	E	
	26	71·45	288·05	618	606	5	·49	44	200	4·54	E	
	27	72·40	286·50	737	640	40	1·22	42	200	4·76	E	
	28	74·30	285·30	773	721	50	1·35	45	200	4·44	F	
	29	75·10	285·06	751	755	9	1·01	52	200	3·84	F	
	30	74·48	285·04	749	736	58	1·50	52	200	3·84	F	
		° ″	° ″									
Velocities taken on the 10th August 1878.	1	10·26	348·26	44	36	4	3·03	119	200	1·12	A	Gauge Reading 37·6 feet at 8 A. M.
	2	23·50	339·	76	88	1	1·28	87	200	2·29	A	
	3	25·32	339·22	78	95	19	1·50	91	200	2·19	A	
	4	30·21	331·40	113	117	46	1·50	64	200	3·12	B	
	5	32·13	327·20	131	126	43	1·38	55	200	3·63	B	
	6	32·43	326·30	137	128	23	1·27	64	200	3·12	B	
	7	36·25	322·18	157	147	12	1·07	55	200	3·63	B	
	8	44·44	314·50	213	198	22	1·18	56	200	3·57	B	
	9	47·46	312·	222	220	14	1·05	51	200	3·92	C	
	10	54·03	305·39	292	275	47	1·32	45	200	4·44	C	
	11	57·38	302·05	321	315	24	1·10	46	200	4·34	C	
	12	60·20	299·30	368	351	20	1·05	45	300	4·44	C	
	13	62·44	297·05	393	388	47	1·31	44	200	4·54	C	
	14	64·32	295·23	436	419	23	1·06	43	200	4·65	D	
	15	65·30	294·20	456	438	12	·55	43	200	4·65	D	
	16	66·07	293·28	482	451	53	1·34	41	200	4·87	D	
	17	66·43	292·50	516	464	24	1·07	43	200	4·65	D	
	18	68·38	291·08	524	511	12	·53	41	200	4·87	D	
	19	69·45	290·15	557	542	51	1·31	40	200	5·00	D	
	20	71·05	288·28	633	583	37	1·19	42	200	4·76	E	
	21	71·44	288·08	620	605	45	1·25	40	200	5·00	E	
	22	72·10	287·40	682	621	0	·41	41	200	4·87	E	
	23	72·38	286·50	737	639	26	1·13	47	200	4·25	E	
	24	73·06	286·30	721	658	13	·58	45	200	4·44	F	
	25	74·10	286·00	698	705	37	1·20	43	200	4·65	F	
	26	73·40	286·02	699	682	22	1·08	46	200	4·34	F	
	27	74·03	285·46	787	699	49	1·40	51	200	3·92	F	
	28	74·24	285·25	768	716	18	1·05	47	200	4·25	F	
	29	74·42	285·45	787	731	15	1·04	49	200	4·08	F	
	30	75·10	284·17	819	755	12	1·01	49	200	4·08	F	

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangy o.

Sub-Surface velocities taken on the 5th of August 1878 at Thapangyo.

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distance reduced from banks. Upper.	Distance reduced from banks. Lower.	Time. Upper.	Time. Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ″	° ″										
	1	43·20	319·00	173	188	38	1·33	55	200	3·63	+½		Boat No. 1.
	2	40·52	319·05	...	...	8	1·05	57	200	3·50			
	3	14·22	338·10	...	...	32	1·33	161	200	3·27			
	4	17·00	338·39	...	...	3	·53	152	200	4·00			$\frac{3·20}{3·63}$ = ·88 B.
	5	35·30	325·40	...	..	59	2·04	65	200	3·07			
	6	36·54	330·48	...	...	24	1·35	71	200	2·81			
	7	21·27	335·48	...	...	51	2·29	98	200	2·04			
	8	36·20	322·45	...	...	3	1·03	60	200	3·33			
									Total	25·65		27	
									Average	3·20			
	1	46·38	315·16	201	211	2	56	54	200	3·70			Boat No. 2.
	2	42·30	315·45	...	...	26	1·19	53	200	3·77			
	3	44·34	313·45	...	...	48	1·40	52	200	3·84			
	4	42·41	314·10	...	...	10	1·02	52	200	3·84			$\frac{3·73}{3·70}$ = 1·00 C.
	5	42·52	314·30	...	...	29	1·18	49	200	4·08			
	6	44·02	313·30	...	...	50	1·40	50	200	4·00			
	7	43·30	314·30	...	...	5	·58	53	200	3·77			
	8	45·10	313·39	...	...	27	1·20	53	200	3·77			
	9	45·30	313·16	...	...	48	1·40	52	200	3·84			
										34·61		31	
										3·73			
	1	48·47	309·05	247	228	47	1·38	51	200	3·92			Boat No. 3.
	2	47·47	309·00	...	...	41	1·00	49	200	4·08			
	3	50·07	308·18	...	...	42	1·26	44	200	4·54			
	4	50·54	307·45	...	...	2	·47	45	200	4·44			$\frac{4·22}{3·92}$ = 1·07 C.
	5	50·07	308·24	...	...	3	·49	46	200	4·34			
	6	50·07	307·26	...	...	25	1·10	45	200	4·44			
	7	51·22	307·59	...	...	33	1·23	50	200	4·00			
	8	49·45	308·20	...	...	4	·50	46	200	4·34			
	9	49·38	308·50	...	...	16	1·06	50	200	4·00			
	10	48·06	310·10	...	...	44	1·32	48	200	4·16			
										42·26		34	
										4·22			
	1	58·43	300·30	353	329	38	1·22	44	200	4·54			
	2	58·43	300·54	...	...	3	·48	45	200	4·44			Boat No. 4.
	3	59·02	300·12	...	...	58	1·39	41	200	4·87			
	4	59·00	300·30	...	...	15	·58	43	200	4·65			
	5	58·43	301·30	...	..	26	1·08	42	200	4·76			$\frac{4·66}{4·54}$ = 1·02 C.
	6	58·30	300·09	...	...	44	1·24	40	200	5·00			
	7	...	300·25	..	...	56	1·38	42	200	4·76			
	8	58·02	299·25	...	...	15	·57	42	200	4·76			
	9	58·24	299·25	...	...	30	1·14	44	200	4·54			
	10	59·13	300·30	...	...	48	1·31	43	200	4·65			
	11	57·52	...	...	...	16	1·02	46	200	4·34			
										51·31		38	
										4·66			
	1	64·10	295·00	429	413	51	1·33	42	200	4·76			
	2	64·47	295·08	...	...	13	·54	41	200	4·87			Boat No. 5.
	3	63·40	295·45	...	...	50	1·31	41	200	4·87			
	4	64·09	295·40	...	...	7	·48	41	200	4·87			
	5	63·47	295·55	...	...	3	·47	44	200	4·54			$\frac{4·92}{4·76}$ = 1·03 D.
	6	64·03	295·45	...	...	23	1·03	40	200	5·00			
	7	64·05	295·10	...	...	14	·56	42	200	4·76			
	8	64·10	295·30	...	...	33	1·13	40	200	5·00			
	9	64·10	295·37	...	...	31	1·10	39	200	5·12			
	10	63·42	295·35	...	...	49	1·28	39	200	5·12			
	11	64·00	295·40	...	...	46	1·24	38	200	5·26			
	12	...	...	...	...	...	...	...	...	...			
										54·17		38	
										4·92			

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo,

Sub-Surface velocities taken on the 5th August 1878, at Thapangyo.—*(continued)*.

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distance required from banks. Upper.	Distance required from banks. Lower.	Time: Upper.	Time: Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ′	° ′										
	1	65·50	293·45	488	445	44	1·27	43	200	4·65			**Boat No. 6.**
	2	...	...	...	...	55	1·36	41	200	4·87			
	3	...	...	...	...	5	·47	42	200	4·76			
	4	65·57	...	...	...	12	·51	39	200	5·12			
	5	...	...	...	...	26	1·07	41	200	4·87			
	6	...	...	...	...	37	1·17	40	200	5·00			$\frac{5·048}{4·65}$ = 1·08 D.
	7	...	...	...	...	35	1·15	40	200	5·00			
	8	...	...	...	...	47	1·25	38	200	5·26			
	9	...	...	...	...	58	1·36	38	200	5·26			
	10	65·30	293·50	...	...	40	1·18	38	200	5·26			
	11	65·57	...	...	...	54	1·31	37	200	5·41			
	12	66·20	...	...	...	9	·48	39	200	5·12			
										60·58		42	
										5·048			
	1	69·23	290·00	549	531	45	1·25	40	200	5·00			**Boat No. 7.**
	2	...	...	...	...	58	1·39	41	200	4·87			
	3	...	...	...	...	6	·47	41	200	4·87			
	4	70·00	289·37	...	...	10	·50	40	200	5·00			
	5	...	...	...	...	17	·57	40	200	5·00			
	6	...	...	...	...	25	1·03	38	200	5·26			$\frac{5·19}{5·00}$ = 1·04 D.
	7	69·55	289·55	...	...	20	·57	37	200	5·41			
	8	...	...	...	...	4	·42	38	200	5·26			
	9	...	...	...	...	55	1·32	37	200	5·41			
	10	69·48	289·45	...	...	20	·57	37	200	5·41			
	11	...	...	...	...	55	1·30	35	200	5·71			
	12	...	...	...	...	10	·46	36	200	5·55			
	13	69·52	290·00	...	...	31	1·13	32	200	4·76			
										67·51		43	
										5·19			
	1	71·26	287·59	696	595	30	1·13	43	200	4·65	+ ½		**Boat No. 8.**
	2	...	...	...	...	46	1·28	42	200	4·76			
	3	...	...	..	...	47	1·29	42	200	4·76			
	4	71·28	...	...	...	39	1·20	41	200	4·87			
	5	...	...	...	...	48	1·30	42	200	4·76			$\frac{4·98}{4·65}$ = 1·07 E.
	6	...	288·05	...	...	5	·46	41	200	4·87			
	7	71·16	...	...	...	57	1·37	40	200	5·00			
	8	...	...	...	...	4	·45	41	200	4·87			
	9	...	288·10	...	...	21	1·00	39	200	5·12			
	10	...	...	...	...	9	·47	38	200	5·26			
	11	71·20	...	...	...	27	1·07	40	200	5·00			
	12	...	...	...	..	37	1·11	54	200	5·88			
										49·80		42	
										4·98			
	1	73·48	286·20	713	688	32	1·15	43	200	4·65			**Boat No. 9.**
	2	...	...	...	...	49	1·33	44	200	4·54			
	3	...	...	...	...	55	1·35	40	200	5·00			
	4	73·16	286·10	...	...	27	1·14	47	200	4·25			
	5	...	...	...	...	33	1·15	42	200	4·76			$\frac{4·58}{4·65}$ = 0·98 F.
	6	73·48	...	...	...	40	1·23	43	200	4·65			
	7	...	286·18	...	...	3	·49	46	200	4·34			
	8	73·10	...	...	...	7	·53	46	200	4·34			
	9	73·45	...	...	...	24	1·09	45	200	4·44			
	10	73·14	286·10	...	...	35	1·16	41	200	4·87			
	11	73·40	...	...	...	54	1·34	40	200	5·00			
	12	73·43	...	...	...	43	1·29	46	200	4·34			
	13	73·54	286·15	..	...	14	1·00	46	200	4·34			
										59·52		43	
										4·58			
	1	74·50	285·15	759	737	11	1·03	52	200	3·84			**Boat No. 10.**
	2	74·50	285·13	...	...	23	1·18	55	200	3·63			
	3	...	285·00	...	...	38	1·25	47	200	4·25			
	4	...	285·15	...	...	45	1·32	47	200	4·25			
	5	75·10	284·55	...	...	47	1·38	51	200	3·92			$\frac{3·96}{3·84}$ = 1·03 F.
	6	75·24	284·55	...	...	3	·56	53	200	3·77			
	7	75·20	284·25	...	...	5	·55	50	200	4·00			
	8	75·36	284·30	...	...	25	1·22	57	200	3·50			
	9	75·15	285·09	...	...	41	1·26	45	200	4·44			
	10	75·00	284·50	...	...	9	1·02	53	200	3·77			
	11	75·00	284·39	...	...	35	1·23	48	200	4·16			
										43·53		39	
										3·96			

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Sub-Surface velocities taken on the 6th August 1878, at Thapangyo.

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distence required from banks. Upper.	Distence required from banks. Lower.	Time. Upper.	Time. Lower.	Line traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ′	° ′										
	1	28·24	331·10	111	108	40	2·01	81	200	2·46			Boat No. 1.
	2	41·50	320·50	...	...	26	1·17	51	200	3·92			
	3	...	319·20	...	...	3	1·08	65	200	3·07			
	4	31·58	328·30	...	...	54	1·54	60	200	3.33			
	5	29·25	330·35	...	...	41	1·43	62	200	3·22			$\frac{3·257}{2·46}$ = 1·32 B.
	6	28·43	328·40	...	...	23	1·23	60	200	3·33			
	7	27·40	320·50	...	...	26	1·20	54	200	3·70			
	8	26·20	325·10	...	...	2	1·08	66	200	3·03			
										26·06		27	
										3·257			
	1	38·50	320·55	173	160	15	1·11	56	200	3·57			Boat No. 2.
	2	38·00	321·03	...	...	41	1·37	56	200	3·57			
	3	32·23	322·30	...	...	57	1·51	54	200	3·70			
	4	36·30	321·30	...	...	24	1·18	54	200	3·70			$\frac{3·53}{3·57}$ = ·98 B.
	5	35·20	321·55	...	...	3	·59	56	200	3·57			
	6	33·44	321·50	...	...	26	1·23	57	200	3·50			
	7	36·08	321·55	...	...	50	1·49	59	200	3·39			
	8	36·27	322·40	...	...	19	1·20	61	200	3·27			
										28·27		28	
										3·53			
	1	52·25	315·55	206	259	23	1·11	48	200	4·16			Boat No. 3.
	2	52·38	...	...	...	42	1·26	44	200	4·54			
	3	50·48	307·12	...	...	58	1·44	46	200	4·34			
	4	51·23	...	...	...	17	1·03	46	200	4·34			
	5	50·40	307·35	...	...	23	1·08	45	200	4·44			$\frac{4·28}{4·16}$ = 1·03 C.
	6	51·54	305·45	...	...	38	1·21	43	200	4·65			
	7	49·30	307·40	...	...	39	1·30	51	200	3·92			
	8	51·28	306·50	...	...	1	·51	50	200	4·00			
	2	51·38	307·05	...	...	8	·55	47	200	4·25			
	10	...	306·30	...	...	27	1·14	·47	200	4·25			
										42·89		35	
										4·28			
	1	62·44	297·00	392	388	9	·51	42	200	4·76			Boat No. 4.
	2	...	297·10	...	...	32	1·15	43	200	4·65			
	3	62·25	297·20	...	...	13	·54	41	200	4·87			
	4	...	...	...	...	25	1·06	41	200	4·87			
	5	61·28	...	...	...	36	1·17	41	200	4·87			$\frac{4·31}{4·76}$ = ·90 C.
	6	62·35	297·10	...	...	26	1·06	40	200	5·00			
	7	63·02	...	...	...	41	1·22	41	200	4·87			
	8	62·00	297·30	...	...	37	1·31	54	200	3·70			
	9	...	297·00	...	...	52	2·14	82	200	2·43			
	10	61·40	297·22	...	...	34	1·28	54	200	3·70			
	11	62·10	...	...	...	46	1·40	54	200	3·70			
	12	61·40	...	...	...	1	...	...	...	...			
										47·42		41	
										4·31			
	1	66·12	293·20	478	453	3	·47	44	200	4·54			Boat No. 5.
	2	66·21	...	...	...	16	·57	41	200	4·87			
	3	66·40	293·20	...	...	3	·46	43	200	4·65			
	4	66·40	...	...	...	13	·55	42	200	4·76			
	5	66·38	...	...	...	22	1·03	41	200	4·87			$\frac{4·70}{4·54}$ = 1·03 D.
	6	66·12	293·39	...	...	37	1·19	42	200	4·76			
	7	66·12	...	...	...	53	1·35	42	200	4·76			
	8	66·30	293·45	...	...	21	1·05	44	200	4·54			
	9	66·30	...	...	...	41	1·22	41	200	4·87			
	10	65·45	293·00	...	...	32	1·14	42	200	4·76			
	11	65·45	...	...	...	51	1·36	45	200	4·44			
	12	65·45	...	...	...	8	·51	43	200	4·65			
										56·47		41	
										4·70			

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo

Sub-Surface velocities taken on the 6th August 1878, at Thapangyo.—*(Continued).*

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distance reduced from banks. Upper.	Distance reduced from banks. Lower.	Time. Upper.	Time. Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ′	° ′										
	1	67·50	292·40	512	490	50	1·31	41	200	4·87	+½		**Boat No. 6.**
	2	.....	.....	...	...	27	1·08	41	200	4·87			
	3	.....	292·35	...	...	36	1·16	40	200	5·00			
	4	67·40	.....	...	...	48	1·29	41	200	4·87			$\frac{4·89}{4·87}$=1·00 D.
	5	.....	.....	...	...	2	·46	44	200	4·54			
	6	.....	.....	...	...	11	·52	41	200	4·87			
	7	.....	292·45	...	...	20	1·04	44	200	4·54			
	8	.....	.....	...	...	23	1·06	43	200	4·65			
	9	.....	.....	...	...	35	1·13	38	200	5·26			
	10	.....	.....	...	...	52	1·33	41	200	4·87			
	11	67·30	292·10	...	...	43	1·20	37	200	5·41			
	12	67·28		...	...	56	1·36	40	200	5·00			
										58·75		42	
										4·89			
	1	69·08	290·39	569	524	12	·53	41	200	4·87			**Boat No. 7.**
	2	.....	.....	...	...	24	1·04	40	200	5·00			
	3	.....	.....	...	...	35	1·16	41	200	4·87			
	4	69·08	290·39	...	...	28	1·07	39	200	5·12			$\frac{5·13}{4·87}$=1·05 D.
	5	.....	.....	...	...	37	1·16	39	200	5·12			
	6	.....	.....	...	...	47	1·25	38	200	5·26			
	7	.....	.....	...	...	1	·43	42	200	4·76			
	8	.....	.....	...	...	9	·50	41	200	4·87			
	9	.....	.....	...	...	24	1·02	38	200	5·26			
	10	.....	.....	...	...	45	1·21	36	200	5·55			
	11	.....	.....	...	...	55	1·32	37	200	5·41			
	12	.....	.....	...	...	12	·48	36	200	5·55			
										61·64		42½	
										5·13			
	1	71·16	288·10	62	589	43	1·26	43	200	4·65			**Boat No. 8.**
	2	71·40	.....	...	...	53	1·34	41	200	4·87			
	3	71·40	.....	...	...	2	·41	39	200	5·12			
	4	71·24	288·03	...	...	52	1·33	41	200	4·87			$\frac{4·89}{4·65}$=1·05 E.
	5	.....	.....	...	...	2	·43	41	200	4·87			
	6	.....	.....	...	...	13	·55	42	200	4·76			
	7	71·14	288·22	...	...	27	1·09	42	200	4·76			
	8	.....	.....	...	...	39	1·21	42	200	4·76			
	9	.....	.....	...	...	48	1·31	43	200	4·65			
	10	71·30	288·16	...	...	9	·49	40	200	5·00			
	11	71·25	.....	...	...	27	1·05	38	200	5·26			
	12	71·46	.....	...	...	38	1·17	39	200	5·12			
										58·69		42	
										4·89			
	1	73·05	286·45	733	657	39	1·22	43	200	4·65			**Boat No. 9.**
	2	.....	.....	...	...	54	1·39	45	200	4·44			
	3	72·37	287·57	...	...	32	1·17	45	200	4·44			
	4	72·46	.....	...	...	47	1·33	46	200	4·34			
	5	73·05	286·55	...	...	41	1·22	41	200	4·87			$\frac{4·67}{4·65}$=1·00 F.
	6	.....	.....	...	...	54	1·34	40	200	5·00			
	7	.....	.....	...	...	40	1·24	44	200	4·54			
	8	.....	.....	...	...	52	1·35	43	200	4·65			
	9	72·32	287·10	...	...	35	1·16	41	200	4·87			
	10	72·42	286·50	...	...	50	1·32	42	200	4·76			
	11	73·25	.....	...	...	35	1·17	42	200	4·76			
	12	72·50	.....	...	...	51	1·33	42	200	4·76			
										56·08			
										4·67		42½	
	1	75·07	284·50	855	752	37	1·35	58	200	3·44			**Boat No. 10.**
	2	.....	.....	...	...	49	1·45	56	200	3·57			
	3	74·40	285·00	...	...	50	1·39	49	200	4·08			$\frac{3·74}{3·44}$=1·09 F.
	4	75·10	.....	...	...	1	·53	52	200	3·84			
	5	74·40	.....	...	...	18	1·07	49	200	4·08			
	6	74·50	285·08	...	...	45	1·42	57	200	3·50			
	7	74·47	.....	...	...	6	1·02	56	200	3·57			
	8	.....	.....	...	...	15	1·13	58	200	3·44			
	9	75·10	284·50	...	...	20	1·12	52	200	3·84			
	10	.....	.....	...	...	34	1·25	51	200	3·92			
	11	.....	.....	...	...	51	1·39	48	200	4·16			
	12	.....	.....	...	...	9	1·06	57	200	3·50			
										44·94		41	
										3·74			

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Sub-Surface velocities taken on the 7th August 1878, at Thapangyo.

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distance reduced from banks. Upper.	Distance reduced from banks. Lower.	Time. Upper.	Time. Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ′	° ′										
	1	30·44	328·10	125	118	2	1·07	65	200	3·07			Boat No. 1.
	2	28·50	330·15	...	...	29	1·31	62	200	3·22			
	3	24·32	331·40	...	...	16	1·23	67	200	2·98			
	4	17·13	332·35	...	...	51	2·29	98	200	2·04			$\frac{2·91}{3·07}$ = ·94 B.
	5	30·16	326·55	...	...	16	1·14	62	200	3·22			
	6	34·00	326·40	...	...	51	1·52	61	200	3·27			
	7	26·00	330·15	...	...	38	1·52	74	200	2·70			
	8	31·08	328·42	...	...	12	1·24	72	200	2·77			
										23·27		29	
										2·91			
	1	43·50	315·50	205	192	19	1·07	48	200	4·16			Boat No. 2.
	2	44·32	...	...	...	42	1·32	50	200	4·00			
	3	...	...	...	...	7	·56	49	200	4·08			
	4	42·34	316·20	...	...	51	1·40	49	200	4·08			$\frac{3·98}{4·16}$ = 95 B.
	5	40·55	317·10	...	...	10	1·01	51	200	3·92			
	6	42·10	...	...	...	21	1·12	51	200	3·92			
	7	43·04	315·25	...	...	41	1·30	49	200	4·08			
	8	39·44	317·30	...	...	55	1·50	55	200	3·63			
	9	39·14	317·25	...	...	13	1·11	58	200	3·44			
										35·31		32	
										3·98			
	1	52·15	306·30	280	258	44	1·40	56	200	3·57			Boat No. 3.
	2	51·35	...	...	...	51	1·41	50	200	4·00			
	3	57·40	...	...	...	...	·51	51	200	3·92			
	4	...	306·42	...	...	20	1·05	45	200	4·44			$\frac{4·18}{3·57}$ = 1·17 C.
	5	...	...	...	...	33	1·22	49	200	4·08			
	6	54·25	305·00	...	...	47	1·31	44	200	4·54			
	7	54·10	304·51	...	...	2	·46	44	100	4·54			
	8	53·56	...	...	...	17	1·05	48	200	4·16			
	9	53·07	305·50	...	...	16	1·00	44	200	4·54			
	10	52·22	306·22	...	...	33	1·22	49	200	4·08			
										41·87		34	
										4·18			
	1	55·50	302·50	330	294	15	·59	44	200	4·54			Boat No. 4.
	2	...	...	...	...	26	1·09	43	200	4·65			
	3	55·18	...	...	...	30	1·13	43	200	4·65			
	4	...	302·45	...	...	50	1·35	45	200	4·44			$\frac{4·368}{4·54}$ = 0·96 C.
	5	...	...	...	...	4	·49	45	200	4·44			
	6	56·22	302·50	...	...	21	1·05	44	200	4·54			
	7	...	...	...	...	39	1·25	46	200	4·34			
	8	55·50	...	...	...	50	1·38	48	200	4·16			
	9	...	...	...	...	5	·55	50	200	4·00			
	10	55·37	303·40	...	...	31	1·22	51	200	3·92			
										43·68		34	
										4·368			
	1	64·26	295·35	440	417	19	1·04	45	200	4·44	+½		Boat No. 5.
	2	64·58	295·35	...	...	41	1·23	42	200	4·76			
	3	...	...	...	...	32	1·15	43	200	4·65			
	4	65·14	...	...	...	41	1·23	42	200	4·76			$\frac{4·60}{4·44}$ = 1·03 D.
	5	...	...	...	...	47	1·30	43	200	4·65			
	6	...	295·10	...	...	52	1·33	41	200	4·87			
	7	...	...	...	...	5	·46	41	200	4·87			
	8	...	...	...	...	17	·58	41	200	4·87			
	9	64·20	295·08	...	...	0	·51	51	200	3·92			
	10	...	...	...	...	23	1·07	44	200	4·54			
	11	...	...	...	...	30	1·16	46	200	4·34			
										50·67		38	
										4·60			

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Sub-Surface velocities on the 7th Augus 1878, at Thapangyo.—*(Continued).*

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distence required from banks. Upper.	Distence required from banks. Lower.	Time. Upper.	Time. Lower.	Line traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ′	° ′										
	1	68·35	291·30	534	509	49	1·29	40	200	5·00			**Boat No. 6.**
	2	.....	.....	...	...	4	·44	40	200	5·00			
	3	68·00	.....	...	...	15	·56	41	200	4·87			
	4	68·08	291·30	...	...	19	1·00	41	200	4·87			$\frac{4·80}{5·00}$ = ·96 D.
	5	67·23	.....	...	...	33	1·14	41	200	4·87			
	6	67·34	.....	...	...	48	1·29	41	200	4·87			
	7	67·50	291·30	...	...	51	1·33	42	200	4·76			
	8	.....	.....	...	...	0	·46	46	200	4·34			
	9	.....	.....	...	...	16	1·00	44	200	4·54			
	10	68·44	291·25	...	...	19	1·03	44	200	4·54			
	11	.....	.....	...	...	31	1·12	41	200	4·87			
	12	67·56	.....	...	...	48	1·27	39	200	5·12			
										57·65		42	
										4·80			
	1	69·57	290·00	549	548	4	·46	42	200	4·76			**Boat No. 7.**
	2	69·05	.....	...	...	20	·59	39	200	5·12			
	3	.....	.....	...	...	27	1·06	39	200	5·12			
	4	.....	290·10	...	...	24	1·05	41	200	4·87			$\frac{4·73}{4·76}$ = ·99 D.
	5	.....	.....	...	...	36	1·19	43	200	4·65			
	6	.....	.....	...	...	46	1·28	42	200	4·76			
	7	69·27	290·38	...	...	22	1·04	42	200	4·76			
	8	.....	.....	...	...	30	1·14	44	200	4·54			
	9	.....	.....	...	...	40	1·23	43	200	4·65			
	10	.....	290·25	...	...	1	·46	45	200	4·44			
	11	.....	.....	...	...	12	·56	44	200	4·54			
	12	.....	.....	...	...	28	1.12	44	200	4·54			
										56·75		42½	
										4·73			
	1	70·30	289·10	586	564	3	·45	42	200	4·76	+½		**Boat No. 8.**
	2	.....	.....	...	...	25	1·05	40	200	5·00			
	3	.....	.....	...	...	33	1·15	42	200	4·76			
	4	70·30	289·00	...	...	33	1·12	39	200	5·12			
	5	70·52	.....	...	...	54	1·33	39	200	5·12			$\frac{5·09}{4·76}$ = 1·07 E.
	6	70·30	.....	...	...	6	·48	42	200	4·76			
	7	70·40	.....	...	...	18	·56	38	200	5·26			
	8	.....	.....	...	...	18	1·00	42	200	4·76			
	9	.....	.....	...	...	28	1·05	37	200	5·41			
	10	.....	.....	...	...	44	1·22	38	200	5·26			
	11	.....	.....	...	...	48	1·25	37	200	5·41			
	12	.....	289·30	...	...	43	1·19	36	200	5·55			
										61·17		42	
										5·09			
	1	73·54	286·08	703	692	51	1·39	48	200	4·16			**Boat No. 9.**
	2	73·40	.....	...	...	6	·50	44	200	4·54			
	3	73·15	.....	...	...	29	1·14	45	200	4·44			
	4	.....	286·45	...	...	38	1·22	44	200	4·54			$\frac{4·46}{4·16}$ = 1·07 F.
	5	73·00	.....	...	...	48	1·33	45	200	4·44			
	6	73·40	.....	...	...	45	1·00	45	200	4·44			
	7	73·28	286·30	...	...	13	·55	42	200	4·76			
	8	.....	.....	...	...	28	1·12	44	200	4·54			
	9	.....	.....	...	...	48	1·37	49	200	4·08			
	10	73·44	286·40	...	...	15	1·01	46	200	4·34			
	11	73·10	286·40	...	...	44	1·27	45	200	4·44			
	12	73·16	286·33	...	...	39	1·26	47	200	4·25			
	13					56	1·36	40	200	5·00			
										57·97		43	
										4·46			
	1	74·48	285·00	747	736	49	1·44	55	200	3·63			**Boat No. 10.**
	2	.....	.....	...	...	3	·55	52	200	3·84			
	3	75·20	284·40	...	...	46	1·38	52	200	3·84			
	4	.....	.....	...	...	58	1·52	54	200	3·70			$\frac{3·89}{3·63}$ = 1·08 F.
	5	74·40	.....	...	...	10	·57	47	200	4·25			
	6	75·14	284·50	...	...	18	1·10	52	200	3·84			
	7	75·00	.....	...	...	43	1·31	52	200	3·84			
	8	75·07	284·55	...	...	41	1·35	54	200	3·70			
	9	.....	.....	...	...	2	·50	48	200	4·16			
	10	.....	.....	...	...	12	1·01	49	200	4·08			
	11	75·12	284·39	...	...	54	1·45	51	200	3·92			
	12	75·30	284·45	...	...	16	1·07	51	200	3·92			
										46·72		41	
										3·89			

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Sub-Surface velocities taken on the 8th August 1878, at Thapangyo.

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distance reduced from banks. Upper.	Distance reduced from banks. Lower.	Time. Upper.	Time. Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ′	° ′										
	1	24·02	334·42	100	89	54	2·20	86	200	2·32	$+\frac{1}{2}$		**Boat No. 1.**
	2	31·10	328·18	...	...	25	1·30	65	200	3·07			
	3	29·42	329·05	...	...	56	2·03	67	200	2·98			
	4	20·30	335·08	...	...	29	2·05	96	200	2·08			
	5	18·00	333·36	...	...	58	2·39	101	200	1·98			$\frac{2·46}{2·32}$=1·06 A.
	6	24·22	.....	...	...	11	1·32	81	200	2·46			
	7	22·08	333·30	...	...	13	1·37	84	200	2·38			
										17·27		26	
										2·46			
	1	36·36	320·03	168	148	35	1·37	62	200	3·22			**Boat No. 2.**
	2	37·50	320·10	...	...	57	1·56	59	200	3·39			
	3	38·20	318·40	...	...	11	1·08	57	200	3·50			
	4	38·40	317·17	...	...	26	1·16	50	200	4·00			
	5	40·32	.....	...	...	43	1·33	50	200	4·00			$\frac{3·53}{3·22}$=1·09 B.
	6	42·25	316·40	...	...	1	·51	50	200	4·00			
	7	40·18	318·50	...	...	53	1·55	62	200	3·22			
	8	40·18	318·55	...	...	17	1·18	61	200	3·27			
	9	40·10	.....	...	...	25	1·27	62	200	3·22			
										31·82		31	
										3·53			
	1	50·37	309·08	248	243	37	1·30	53	200	3·77			**Boat No. 3.**
	2	47·53	309·55	...	...	53	1·43	50	200	4·00			
	3	.....	.....	...	...	6	·56	50	200	4·00			
	4	50·22	308·10	...	...	43	1·28	45	200	4·44			$\frac{3·98}{3·77}$=1·06 C.
	5	.....	.....	...	...	57	1·43	46	200	4·34			
	6	48·38	309·30	...	...	10	1·01	51	200	3·92			
	7	51·20	308·40	...	...	55	1·46	51	200	3·92			
	8	49·02	.....	...	...	10	1·02	52	200	3·84			
	9	50·40	308·40	...	...	24	1·18	54	200	3·70			
	10	49·44	309·00	...	...	32	1·23	51	200	3·92			
										39·85		35	
										3·98			
	1	60·30	299·50	373	353	42	1·26	44	200	4·54			**Boat No. 4.**
	2	60·20	299·20	...	...	56	1·40	44	200	4·54			
	3	59·15	299·20	...	...	5	·50	45	200	4·44			
	4	60·20	.....	...	...	16	1·02	56	200	4·34			$\frac{4·53}{4·54}$= ·99 C.
	5	.....	.....	...	...	26	1·12	46	200	4·34			
	6	.....	.....	...	...	38	1·25	47	200	4·25			
	7	.....	.....	...	...	42	1·27	45	200	4·44			
	8	.....	.....	...	...	57	1·40	43	200	4·65			
	9	.....	.....	...	...	9	·51	42	200	4·76			
	10	.....	.....	...	...	17	·58	41	200	4·87			
	11	.....	.....	...	...	36	1·19	43	200	4·65			
										49·82		38	
										4·53			
	1	67·45	292·40	512	488	23	1·06	43	200	4·65			**Boat No. 5.**
	2	.....	.....	...	...	33	1·15	42	200	4·76			
	3	67·20	292·50	...	...	12	·54	42	200	4·76			
	4	.....	.....	...	...	29	1·11	42	200	4·76			
	5	.....	.....	...	...	4	·45	41	200	4·87			
	6	.....	.....	...	...	17	·58	41	200	4·87			$\frac{4·91}{4·65}$=1·06 D.
	7	.....	.....	...	...	46	1·28	42	200	4·76			
	8	.....	.....	...	...	57	1·39	42	200	4·76			
	9	.....	.....	...	...	15	·54	39	200	5·12			
	10	.....	.....	...	...	4	·43	39	200	5·12			
	11	.....	.....	...	...	15	·53	38	200	5·26			
	12	.....	.....	...	...	25	1·03	38	200	5·26			
		.....	.....	...	...								
										58·95		42	
										4·91			

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Sub-Surface velocities taken 8th August 1878, at Thapangyo.—*(Continued.)*

Date of observation.	Number of floats.	Angle: Upper.	Angle: Lower.	Distance required from banks: Upper.	Distance required from banks: Lower.	Time: Upper.	Time: Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ″	° ″										
	1	69·43	290·08	553	541	39	1·22	43	200	4·65			
	2	.....	.....	...	...	53	1·34	41	200	4·87			Boat No. 6.
	3	70·00	284·50	...	...	59	1·34	35	200	5·71			
	4	69·55	290·10	...	...	12	1·52	40	200	5·00			
	5	.....	.....	...	...	24	1·04	40	200	5·00			$\frac{5·13}{4·65}$=1·10 D.
	6	.....	.....	...	...	31	1·11	40	200	5·00			
	7	.....	.....	...	...	46	1·28	42	200	4·76			
	8	.....	.....	...	...	55	1·33	38	200	5·26			
	9	.....	.....	...	...	47	1·27	40	200	5·00			
	10	.....	.....	...	...	59	1·35	36	200	5·55			
	11	.....	.....	...	...	13	·51	38	200	5·26			
	12	.....	.....	...	...	50	1·26	36	200	5·55			
										61·61		42	
										5·13			
	1	70·57	288·50	647	579	36	1·18	42	200	4·76			Boat No. 7.
	2	.....	.....	...	...	46	1·25	39	200	5·12			
	3	.....	289·10	...	...	40	1·19	39	200	5·12			
	4	.....	.....	...	...	53	1·33	40	200	5·00			$\frac{5·15}{4·76}$=1·09 E.
	5	71·15	288·50	...	...	44	1·23	39	200	5·12			
	6	71·34	.....	...	...	56	1·34	38	200	5·26			
	7	70·30	.....	...	...	59	1·39	40	200	5·00			
	8	.....	.....	...	...	11	·51	40	200	5·00			
	9	.....	.....	...	...	9	·47	38	200	5·26			
	10	.....	.....	...	...	25	1·03	38	200	5·26			
	11	.....	.....	...	...	6	·44	38	200	5·26			
	12	.....	.....	...	...	22	·57	35	200	5·71			
										61·87		42	
										5·15			
	1	71·30	288·40	640	597	50	1·30	40	200	5·00			Boat No. 8.
	2	.....	.....	...	...	6	·47	41	200	4·87			
	3	71·00	.....	...	...	13	·51	38	200	5·26			
	4	.....	288·50	...	...	40	1·20	40	200	5·00			$\frac{5·00}{5·00}$=1·00 E.
	5	70·30	.....	...	...	51	1·30	39	200	5·12			
	6	71·00	.....	...	...	57	1·39	42	200	4·76			
	7	.....	.....	...	...	26	1·05	39	200	5·12			
	8	.....	.....	...	...	35	1·18	43	200	4·65			
	9	.....	.....	...	...	49	1·31	42	200	4·76			
	10	.....	.....	...	...	43	1·23	40	200	5·00			
	11	.....	.....	...	...	59	1·39	40	200	5·00			
	12	.....	.....	...	...	12	·49	37	200	5·41			
	13	.....	.....	...	...	10	·49	39	200	5·12			
										65·07		43	
										5·00			
	1	72·40	286·20	713	640	36	1·21	45	200	4·44			Boat No. 9.
	2	.....	.....	...	...	42	1·27	45	200	4·44			
	3	.....	.....	...	...	53	1·31	38	200	5·26			
	4	73·25	286·25	...	...	54	1·41	47	200	4·25			
	5	72·48	.....	...	...	21	1·06	45	200	4·44			$\frac{4·47}{4·44}$=1·00 E.
	6	.....	.....	...	...	39	1·23	44	200	4·54			
	7	.....	.....	...	...	7	·57	50	200	4·00			
	8	.....	.....	...	...	21	1·11	50	200	4·00			
	9	.....	.....	...	...	35	1·23	48	200	4·16			
	10	.....	.....	...	...	57	1·40	43	200	4·65			
	11	.....	.....	...	...	18	1·03	45	200	4·44			
	12	.....	.....	...	...	31	1·11	40	200	5·00			
										53·62		42½	
										4·47			
	1	75·12	284·50	855	756	57	1·54	57	200	3·50			Boat No. 10.
	2	.....	.....	...	...	8	1·00	52	200	3·84			
	3	.....	.....	...	...	18	1·14	56	200	3·57			
	4	.....	.....	...	...	11	1·10	59	200	3·39			
	5	75·00	284·59	...	...	18	1·11	53	200	3·77			$\frac{3·72}{3·50}$=1·06 F.
	6	.....	.....	...	...	27	1·17	50	200	4·00			
	7	.....	.....	...	...	44	1·35	51	200	3·92			
	8	.....	.....	...	...	2	·54	52	200	3·84			
	9	.....	.....	...	...	21	1·12	51	200	3·92			
	10	.....	.....	...	...	42	1·38	56	200	3·57			
	11	.....	.....	...	...	58	1·51	53	200	3·77			
	12	.....	.....	...	...	9	1·05	56	200	3·57			
										44·66		41	
										3·72			

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distance reduced from banks. Upper.	Distance reduced from banks. Lower.	Time. Upper.	Time. Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ″	° ″										
Sub-Surface velocities taken on the 9th August 1878, at Thapangyo.	1	25·32	333·21	103	95	40	2·03	83	200	2·41			Boat No. 1.
	2	30·17	.....	...	...	8	1·19	71	200	2·81			
	3	24·32	332·25	...	...	52	2·07	75	200	2·66			
	4	24·32	.....	...	...	53	2·06	73	200	2·74			$\frac{2·67}{2·41}$ = 1·10 A.
	5	.....	.....	...	...	24	1·37	73	200	2·74			
	6	.....	.....	...	...	50	2·01	71	200	2·81			
	7	.....	332·40	...	...	26	1·45	79	200	2·53			
										18·70		26	
										2·67			
	1	38·30	324·20	147	159	43	1·40	57	200	3·50			Boat No. 2.
	2	38·10	320·40	...	...	54	1·45	51	200	3·92			
	3	37·28	323·20	...	...	21	1·16	55	200	3·63			
	4	38·55	320·10	...	...	39	1·34	55	200	3·63			
	5	29·20	.....	...	...	55	1·50	55	200	3·63			$\frac{3·49}{3·50}$ = ·99 B.
	6	.....	.....	...	...	35	1·35	60	200	3·33			
	7	.....	.....	...	...	54	1·55	61	200	3·27			
	8	.....	.....	...	...	13	1·18	65	200	3·07			
										27·98		28	
										3·49			
	1	47 10	312·25	225	215	2	·53	51	200	3·92			Boat No. 3.
	2	.....	.....	...	...	7	·59	52	200	3·84			
	3	47·00	312·20	...	...	30	1·23	53	200	3·77			
	4	.....	.....	...	...	48	1·38	50	200	4·00			$\frac{3·76}{3·92}$ = ·96 C.
	5	.....	.....	...	...	14	1·07	53	200	3·77			
	6	.....	.....	...	...	37	1·29	52	200	3·84			
	7	.....	.....	...	...	54	1·48	54	200	3·70			
	8	.....	.....	...	...	12	1·07	55	200	3·63			
	9	.....	.....	...	...	27	1·26	59	200	3·39			
										33·86		32	
										3·76			
	1	53·50	306·50	283	273	13	1·01	48	200	4·16			Boat No. 4.
	2	.....	.....	...	...	28	1·16	48	200	4·16			
	3	53·50	306·25	...	...	38	1·24	46	200	4·34			
	4	.....	.....	...	...	0	·47	47	200	4·25			$\frac{4·05}{4·16}$ = ·97 C.
	5	.....	.....	...	...	13	1·02	49	200	4·08			
	6	.....	.....	...	...	24	1·13	49	200	4·08			
	7	.....	.....	...	...	39	1·30	51	200	3·91			
	8	.....	.....	...	...	51	1·41	50	200	4·00			
	9	.....	.....	...	...	6	1·00	54	200	3·70			
	10	.....	.....	...	...	23	1·15	52	200	3·84			
										40·52		35	
										4·05			
	1	63·20	296·30	419	398	29	1·13	44	200	4·54			Boat No. 5.
	2	62·40	.....	...	...	44	1·28	44	200	4·54			
	3	62·48	.....	...	...	55	1·39	44	200	4·54			
	4	.....	296·50	...	...	25	1·07	42	200	4·76			$\frac{4·599}{4·54}$ = 1·01 C.
	5	.....	.....	...	...	38	1·21	43	200	4·65			
	6	.....	.....	...	...	55	1·37	42	200	4·76			
	7	.....	.....	...	...	11	·54	43	200	4·65			
	8	.....	.....	...	...	24	1·07	43	200	4·65			
	9	.....	.....	...	...	41	1·24	43	200	4·65			
	10	.....	.....	...	...	30	1·17	47	200	4·25			
										45·99		36	
										4·599			

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River, at Thapangyo.

Sub-Surface velocities taken on the 9th August 1878 at Thapangyo.—*(Continued.)*

Date of observation.	Number of floats.	Angle: Upper.	Angle: Lower.	Distance required from banks: Upper.	Distance required from banks: Lower.	Time: Upper.	Time: Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ″	° ″										
	1	67·57	291·05	523	493	46	1·30	44	200	4·54			**Boat No. 6.**
	2	67·40	291·25	...	...	11	·44	43	200	4·65			
	3	.....	.....	...	...	17	·59	42	200	4·76			
	4	68·04	291·55	...	...	25	1·06	41	200	4·87			$\frac{4·61}{4·54}$ = 1·01 D.
	5	.....	.....	...	...	37	1·20	43	200	4·65			
	6	.....	.....	...	...	49	1·30	41	200	4·87			
	7	.....	.....	...	...	55	1·37	42	200	4·76			
	8	.....	.....	...	...	4	·50	46	200	4·34			
	9	.....	.....	...	...	14	·56	42	200	4·76			
	10	.....	.....	...	...	13	·55	42	200	4·76			
	11	.....	.....	...	...	24	1·08	44	200	4·54			
	12	.....	.....	...	...	37	1·29	52	200	5·84			
										55·34		41	
										4·61			
	1	69·20	290·12	555	530	8	·50	42	200	4·76			**Boat No. 7.**
	2	69·35	290·08	...	...	20	1·00	40	200	5·00			
	3	.....	.....	...	...	55	1·37	42	200	4·76			
	4	69·30	290·10	...	...	19	1·02	43	200	4·65			$\frac{4·81}{4·76}$ = 1·01 D.
	5	.....	.....	...	...	38	1·22	44	200	4·54			
	6	.....	.....	...	...	43	1·27	44	200	4·54			
	7	.....	.....	...	...	57	1·38	41	200	4·87			
	8	.....	.....	...	...	28	1·11	43	200	4·65			
	9	.....	.....	...	...	44	1·23	39	200	5·12			
	10	.....	.....	...	...	44	1·25	41	200	4·87			
	11	.....	.....	...	...	56	1·37	41	200	4·87			
	12	.....	.....	...	...	51	1·30	39	200	5·12			
										57·75		40	
										4·81			
	1	71·07	288·50	647	584	40	1·21	42	200	4·87	+½		**Boat No. 8**
	2	71·00	288·50	...	...	55	1·36	41	200	4·87			
	3	.....	.....	...	...	6	1·48	45	200	4·76			
	4	.....	.....	...	...	45	1·28	43	200	4·65			$\frac{4·837}{4·87}$ = ·9 E.
	5	.....	.....	...	...	47	1·31	38	200	4·54			
	6	.....	.....	...	...	59	1·41	38	200	4·76			
	7	.....	.....	...	...	14	·55	41	200	4·87			
	8	.....	.....	...	...	23	1·08	45	200	4·44			
	9	.....	.....	...	...	38	1·21	43	200	4·65			
	10	.....	.....	...	...	51	1·29	38	200	5·26			
	11	.....	.....	...	...	3	·41	38	200	5·26			
	12	.....	.....	...	...	5	·44	39	200	5·12			
										58·05		42	
										4·837			
	1	73·42	286·30	721	683	13	1·02	49	200	4·08			**Boat No. 9.**
	2	.....	.....	...	...	21	1·08	47	200	4·25			
	3	.....	.....	...	...	29	1·15	46	200	4·34			
	4	.....	.....	...	...	34	1·16	42	200	4·76			$\frac{4·25}{4·08}$ = 1·04 F.
	5	.....	.....	...	...	49	1·34	45	200	4·44			
	6	.....	.....	...	...	14	·59	45	200	4·44			
	7	.....	.....	...	...	19	1·03	44	200	4·54			
	8	.....	.....	...	...	31	1·22	51	200	3·92			
	9	.....	.....	...	...	41	1·29	48	200	4·16			
	10	.....	.....	...	...	17	1·04	47	200	4·25			
	11	.....	.....	...	...	27	1·14	47	200	4·25			
	12	.....	.....	...	...	32	1·23	51	200	3·92			
	13	.....	.....	...	...	44	1·35	51	200	3·92			
										55·25		43	
										4·35			
	1	74·55	284·45	849	742	13	1·10	57	200	3·50			**Boat No. 10.**
	2	.....	.....	...	...	10	1·03	53	200	3·77			
	3	.....	.....	...	...	50	1·45	55	200	3·63			
	4	.....	.....	...	...	16	1·08	52	200	3·84			$\frac{3·82}{3·50}$ = 1·09 F.
	5	75·00	284·57	...	...	40	1·38	58	200	3·44			
	6	.....	.....	...	...	36	1·27	51	200	3·92			
	7	.....	.....	...	...	7	·57	50	200	4·00			
	8	.....	.....	...	...	30	1·21	51	200	3·92			
	9	.....	.....	...	...	40	1·32	52	200	3·84			
	10	.....	.....	...	...	56	1·46	50	200	4·00			
	11	.....	.....	...	...	2	·50	48	200	4·16			
										42·02		38	
										3·82			

Appendix II.—continued.

Showing float observations for discharye on the Nawoon River, ot Thapangyo

Sub-Surface velocities taken on the 10th August 1878 at Thapangyo.

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distance reduced from banks. Upper.	Distance reduced from banks. Lower.	Time. Upper.	Time. Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ″	° ″										
	1	29·10	330·20	117	111	13	1·20	67	200	2·98			Boat No. 1.
	2	31·10	.....	...	...	33	1·38	65	200	3·07			
	3	35·20	325·50	...	...	0	·58	58	200	3·44			
	4	26·58	331·50	...	...	37	1·45	68	200	2·94			$\frac{3·10}{2·98}$ = 1·04 B.
	5	30·00	.....	...	...	49	1·51	62	200	3·22			
	6	27·22	330·50	...	...	39	1·43	64	200	3·12			
	7	31·30	.....	...	...	2	1·01	59	200	3·39			
	8	26·00	.....	...	...	37	1·54	74	200	2·70			
										24·86 3·107		27	
	1	45·36	313·59	221	204	56	1·47	51	200	3·92			Boat No. 2.
	2	43·00	.....	...	...	15	1·08	53	200	3·77			
	3	43·00	315·10	...	...	21	1·11	50	200	4·00			
	4	44·00	.....	...	...	43	1·30	47	200	4·25			
	5	44·47	315·20	...	...	52	1·40	48	200	4·16			$\frac{3·95}{3·92}$ = 1·00 C.
	6	.....	.....	...	...	0	·50	50	200	4·00			
	7	.....	.....	...	...	6	·57	51	200	3·92			
	8	.....	.....	...	...	23	1·16	53	200	3·77			
	9	.....	.....	...	..	43	1·31	48	200	4·16			
	10	.....	.....	...	...	33	1·29	56	200	3·57			
										39·52 3·95		34	
	1	51·10	307·45	272	248	43	1·29	46	200	4·34			Boat No. 3.
	2	50·45	.....	...	...	55	1·41	46	200	4·34			
	3	.....	.....	...	...	0	·46	46	200	4·34			
	4	51·10	308·38	...	...	20	1·09	49	200	4·08			$\frac{4·027}{4·34}$ = 9·2 C.
	5	.....	308·25	...	...	41	1·30	49	200	4·08			
	6	.....	.....	...	...	49	1·38	49	200	4·08			
	7	.....	.....	...	...	2	·56	54	200	3·70			
	8	.....	.....	...	...	42	1·35	53	200	3·77			
	9	.....	.....	...	...	50	1·43	53	200	3·77			
	10	.....	.....	...	...	4	·57	53	200	3·77			
										40·27 4·027		33½	
	1	60·10	299·40	370	348	25	1·09	44	200	4·54			Boat No. 4.
	2	.....	.....	..	...	34	1·18	44	200	4·54			
	3	.....	.....	...	...	44	1·27	43	200	4·65			
	4	.....	.....	...	...	54	1·39	45	200	4·44			
	5	59·47	299·50	...	...	2	·46	44	200	4·54			$\frac{4·38}{4·54}$ = 9·96 C.
	6	.....	.....	...	...	12	·57	45	200	4·44			
	7	.....	.....	...	...	22	1·09	47	200	4·25			
	8	.....	.....	...	...	48	1·38	50	200	4·00			
	9	.....	.....	...	...	57	1·45	48	200	4·16			
	10	.....	.....	...	...	10	·57	47	200	4·25			
										43·81 4·38			
	1	63·33	296·10	413	402	35	1·19	44	200	4·54			Boat No. 5.
	2	.....	.....	...	...	43	1·26	43	200	4·65			
	3	.....	.....	...	...	47	1·31	44	200	4·54			
	4	.....	.....	...	...	57	1·43	46	200	4·34			
	5	63·30	296·20	...	...	29	1·14	45	200	4·44			$\frac{4·41}{4·54}$ = ·97 D.
	6	.....	.....	...	...	38	1·21	43	200	4·65			
	7	.....	.....	...	...	46	1·30	44	200	4·54			
	8	.....	.....	...	...	11	·56	45	200	4·44			
	9	.....	.....	...	...	22	1·06	44	200	4·54			
	10	.....	.....	...	...	34	1·24	50	200	4·00			
	11	.....	.....	...	...	13	1·01	48	200	4·16			
	12	.....	.....	...	...	30	1·18	48	200	4·16			
										53·00 4·41		39½	

Appendix II.—continued.

Showing float observations for discharge on the Nawoon River at Thapangyo.

Sub-Surface velocities on the 10th August 1878, at Thapangyo.—*(Continued).*

Date of observation.	Number of floats.	Angle. Upper.	Angle. Lower.	Distance reduced from banks. Upper.	Distance reduced from banks. Lower.	Time. Upper.	Time. Lower.	Time traversed in second.	Distance in feet.	Velocities per second in feet.	Wind.	Depth.	Remarks.
		° ″	° ″										
	1	70·55	289·15	589	578	51	1·33	42	200	4·76			**Boat No. 6.**
	2	.....	.....	...	...	59	1·39	40	200	5·00			
	3	70·40	289·20	...	...	6	·46	40	200	5·00			
	4	.....	.....	...	...	39	1·17	45	200	4·44			$\frac{4·58}{4·76}$ = ·96 E.
	5	.....	.....	...	...	41	1·26	45	200	4·44			
	6	.....	.....	...	...	52	1·33	41	200	4·87			
	7	.....	.....	...	...	8	·51	43	200	4·65			
	8	.....	.....	...	...	18	1·05	47	200	4·25			
	9	.....	.....	...	...	33	1·19	46	200	4·34			
	10	.....	.....	..	...	26	1·10	44	200	4·54			
	11	.....	.....	...	...	37	1·23	46	200	4·34			
	12	.....	.....	...	...	48	1·33	45	200	4·44			
										55·07		42½	
										4·58			
	1	71·57	287·40	682	613	44	1·24	40	200	5·00			**Boat No. 7.**
	2	.....	.....	...	...	53	1.36	43	200	4·65			
	3	72·30	287·20	...	...	5	·49	44	200	4·54			
	4	.....	.....	...	...	31	1·12	41	200	4·87			
	5	71·37	287·59	...	...	39	1·18	39	200	5·12			$\frac{4·78}{5·00}$ = 95 E.
	6	.....	.....	...	...	49	1·29	40	200	5·00			
	7	.....	.....	...	...	0	·42	42	200	4·76			
	8	.....	.....	...	...	10	·55	45	200	4·44			
	9	.....	.....	...	...	25	1·07	42	200	4·76			
	10	.....	.....	...	...	28	1·08	40	200	5·00			
	11	.....	.....	...	...	41	1·23	42	200	4·76			
	12	.....	.....	...	...	56	1·40	44	200	4·54			
										57·44		42	
										4·78			
	1	74·15	286·50	737	709	16	1·02	46	200	4·34			**Boat No. 8.**
	2	.....	.....	...	...	21	1·07	46	200	4·34			
	3	73·15	286·43	...	...	33	1·16	43	200	4·65			
	4	73·14	286·20	...	...	20	1·01	41	200	4·87			$\frac{4·80}{4·34}$ = 1·10 F.
	5	73·30	286·40	...	...	28	1·08	40	200	5·00			
	6	.....	.....	...	...	42	1·22	40	200	5·00			
	7	.....	.....	...	...	10	·51	40	200	5·00			
	8	.....	.....	...	...	21	1·04	43	200	4·65			
	9	.....	.....	...	...	37	1·20	43	200	4·65			
	10	.....	.....	...	...	43	1·23	40	200	5·00			
	11	.....	.....	...	...	55	1·32	37	200	5·41			
	12	.....	.....	...	...	6	·46	40	200	5·00			
	13	.....	.....	...	...	56	1·40	44	200	4·54			
										62·45		43	
										4·80			
	1	74·17	285·30	773	710	13	·59	46	200	4·34			**Boat No. 9.**
	2	74·40	285·10	...	...	22	1·07	45	200	4·44			
	3	74·35	285·08	...	...	33	1·19	46	200	4·34			
	4	.....	.....	...	...	44	1·30	46	200	4·34			
	5	.....	.....	...	...	13	·58	45	200	4·44			$\frac{4·33}{4·34}$ = ·99 F.
	6	.....	.....	...	...	33	1·20	47	200	4·25			
	7	.....	.....	...	...	45	1·29	44	200	4·54			
	8	.....	.....	...	...	48	1·37	49	200	4·08			
	9	.....	.....	...	...	50	1·39	49	200	4·08			
	10	.....	.....	...	...	2	·47	45	200	4·44			
	11	.....	.....	...	...	20	1·05	45	200	4·44			
	12	.....	.....	...	...	33	1·20	47	200	4·25			
										51·98		42	
										4·33			
	1	74·50	284·50	855	737	11	1·06	55	200	3·63			**Boat No. 10.**
	2	75·28	284·49	...	...	18	1·12	54	200	3·70			
	3	75·40	284·30	..	...	24	1·19	55	200	3·63			
	4	75·50	284·15	...	...	11	1·05	54	200	3·70			
	5	.....	.....	...	...	22	1·12	50	200	4·00			$\frac{3·60}{3·63}$ = ·99 F.
	6	.....	.....	...	...	31	1·25	54	200	3·70			
	7	.....	.....	...	...	53	1·46	53	200	3·77			
	8	.....	.....	...	...	3	·59	56	200	3·57			
	9	.....	.....	...	...	19	1·21	62	200	3·22			
	10	.....	.....	...	...	39	1·37	58	200	3·44			
	11	.....	.....	...	...	59	1·56	57	200	3·50			
	12	.....	.....	...	...	11	1·10	59	200	3·39			
										43·25		42	
										3·60			

Appendix II.—continued.

Reduction of velocity observations for the discharge of the Nawoon at Thapangyo.

Gauge Reading.	Difference.	Areas. A.	B.	C.	D.	E.	F.	Total Areas.	Velocities. A.	B.	C.	D.	E.	F.	Proportional Numbers. A.	B.	C.	D.	E.	F.	Velocities and Areas. A.	B.	C.	D.	E.	F.	Total in C. feet per second.	C. Metres per day.
8·10	1·90	100 2,124	100 3,590	200 6,950	150 5,924	100 4,210	180 6,505	29,303	2·09	3·96	4·44	4·72	4·92	3·73	100	200	400	550	650	830	1·08	1·02	1·00	1·02	1·04	1·03	1·08	1·02
8·17	1·83	190 1,934	190 3,400	380 6,570	285 5,639	190 4,020	342 6,163	27,726	14·62	7·92	17·78	28·36	14·76	29·85	1·61 2·17	8·22 3·38 3·50 4·00	[31·69	14·41	29·27	30·73	1·45 1·88 1·94 2·04	3·39 2·46 2·89 3·70 3·77 4·00	4·00 4·03 4·25 4·25 4·34 4·44	4·65 4·87 4·87 4·87 4·87	4·65 4·87 4·87 4·87 4·87	4·44 4·44 3·84	1·07 1·08	1·07 1·08	1·07 1·08
8·17	1·83	183 1,941	183 3,407	366 6,584	274·50 5,649·5	183 4,027	329·40 6,175·6	27,784·10	3·78	3·57	4·62	4·80	4·87	4·39	2·29 2·32	3·57 3·27 3·27 3·57	4·00 4·54 4·54 4·65 4·76 4·76	4·87 5·00 4·54	4·65 5·12 5·00 4·65	4·76 4·87 4·87 4·34 4·25 4·16 4·76 3·70	2·30 2·32	3·39 2·46 2·89 3·70 3·77 4·00	4·00 4·03 4·25 4·25 4·34 4·44	4·65 4·87 4·87 4·87 4·87	4·76 4·87 4·87 4·87 4·87	4·65 4·87 4·87 4·87 4·87	1·06	1·09 1·00 1·00	1·06 1·10
8·17	1·83	183 1,941	183 3,407	366 6,584	274·50 5,649·5	183 4,027	329·40 6,175·6	27,784·10	7·31	20·21	25·36	23·58	29·00	12·72	1·37 2·50 2·70	2·46 2·98 3·70 3·63 3·50 3·57	4·16 4·25 4·44	4·65 4·87 4·65 4·87 4·65 4·87 4·76 4·76 4·76 4·76	4·87 4·76 4·76 4·54 4·76	4·44 4·44 3·84	1·06	1·06 1·10	1·09 1·00 1·00	1·07 1·08	1·06	1·06	1·06
8·07	1·93	193 1,931	193 3,397	386 6,564	289·50 5,684·5	193 4,017	347·40 6,167·6	27,701·10	6·57	19·84	12·85	47·32	23·69	12·12	1·12 2·29 2·19	8·12 3·63 3·12 3·63 3·57	4·44 4·65 4·34 3·92 4·25 4·08 4·06	4·65 4·87 4·87 4·87 4·87 4·87	4·76 5·00 4·87 4·25	4·44 4·65 4·34 3·92 4·25 4·08 4·06	1·10	1·04	1·01	1·04	1·04	1·04	1·10	1·04
8·05	1·95	195 1,929	195 3,395	390 6,560	292·50 5,631·5	195 4,015	351 6,154	27,684·5	5·60	17·07	21·66	28·69	18·88	29·76	1·86 1·12 2·29 2·19	8·41 3·96 3·51 3·57	4·38 4·28 4·23 4·36 4·62 4·44	4·78 4·73 4·76 4·80 4·71 4·76 4·83 4·87 4·39 4·24 4·04 4·25	4·72 4·73 4·83 4·87 4·39 4·24 4·04 4·25	4·25 4·04 4·08 4·06	1·86 1·12 2·29 2·19	8·41 3·96 3·51 3·57	4·38 4·28 4·23 4·36 4·62 4·44	4·78 4·73 4·76 4·80 4·71 4·76 4·83 4·87 4·39 4·24 4·04 4·25	4·72 4·73 4·83 4·87 4·39 4·24 4·04 4·25	4·25 4·04 4·08 4·06	1·86 1·12 2·29 2·19	8·41 3·96 3·51 3·57	4·38 4·28 4·23 4·36 4·62 4·44	4·78 4·73 4·76 4·80 4·71 4·76 4·83 4·87 4·39 4·24 4·04 4·25	4·72 4·73 4·83 4·87 4·39 4·24 4·04 4·25	4·25 4·04 4·08 4·06

Velocities and Areas.																													
A.	1·08	3,875=3·5885689	4,667=3·6596602	8,815=3·551620T	4,321=3·6381771	3,962=3·6979111	4,365=3·6400266	1,929 1·86	3·3853932 2·6951129	1·981 3·2857828 3·04441	1·941 3·2880255 2·30071	1·941 3·2880255 2·30178	1·941 3·2880255 1·89276	1·934 3·2864565 2·09 3·2014G3	2·16 1·08						3·875=3·5885689	4,667=3·6596602	8,815=3·551620T	4,321=3·6381771	3,962=3·6979111	4,365=3·6400266	118,076=5·0721414 3·38853	8·4600714= 288 849 800 8·4600714= 288 849 800
B.	1·02	11,808=4·0721944	11,455=4·0662096	11,676=4·0678116	11,981=4·0787914	12,198=4·0862794	18,733=4·1877748	3,395 3·3303839 3·41 3·3375544	3,397 3·3310965 3·30 3·3185139	3,407 3·3323723 3·36 3·3263393	3,407 3·3323723 3·45 3·3781917	3,407 3·3323723 3·36 3·3263393	3,400 3·3314789 3·96 3·5970952	1·02	1·02	1·02	1·02	1·02	1·02	1·02	11,808=4·0721944	11,455=4·0662096	11,676=4·0678116	11,981=4·0787914	12,198=4·0862794	18,733=4·1877748	118,076=5·0721414 3·38853	8·4600714= 288 849 800 8·4600714= 288 849 800
C.	1·00	28,405=4·4538917	28,094=4·4486124	27,784=4·4438623	29,760=4·4736282	28,706=4·4579763	29,171=4·4649484	6,500 8·8160938 4·33 8·8160938 1·00 ..	6,564 8·8171686 4·28 8·8144438 1·00 ..	6,584 8·8184898 4·22 8·8184898 1·00 ..	6,584 8·8184898 4·52 8·8551384 1·00 ..	6,584 8·8184898 4·36 8·8934865 1·00 ..	6,570 8·8177654 4·44 8·8473830 1·00 ..	1·00	1·00	1·00	1·00	1·00	1·00	1·00	28,405=4·4538917	28,094=4·4486124	27,784=4·4438623	29,760=4·4736282	28,706=4·4579763	29,171=4·4649484	118,499=5·0796850 3·38853	8·4636216= 288 827 800
B.	1·02	27,457=4·4386522	27,184=4·4384167	27,141=4·4386311	27,660=4·4418514	27,429=4·4382172	27,145=4·4337443	6,631·50 8·7506341 4·78 8·7506341 1·02 ..	6,634·50 8·7608554 4·73 8·7608554 1·02 ..	6,649·50 8·7520100 4·71 8·7520100 1·02 ..	6,649·50 8·7520100 4·80 8·7520100 1·02 ..	5,649·5 8·7520100 4·76 8·7520100 1·02 ..	5,689 8·7513021 4·72 8·7513021 1·02 ..	1·02	1·02	1·02	1·02	1·02	1·02	1·02	27,457=4·4386522	27,184=4·4384167	27,141=4·4386311	27,660=4·4418514	27,429=4·4382172	27,145=4·4337443	118,069=5·0796849 3·38853	8·4606361= 288 825 800
A.	1·08	3,875=3·5885689	4,667=3·6596602	8,815=3·5516207	4,321=3·6381771	3,962=3·6979111	4,365=3·6400266	1,934 1·86	3·2864565 2·6951129	1·981 3·2857828 3·04441	1·941 3·2880255 2·30071	1·941 3·2880255 1·89276	1·941 3·2880255 2·09 3·2014G3	1·934 3·2864565 2·09 3·2014G3	2·16 1·08						3·875=3·5885689	4,667=3·6596602	8,815=3·5516207	4,321=3·6381771	3,962=3·6979111	4,365=3·6400266	118,499=5·0796850 3·38853	8·4636216= 289 827 800
B.	1·02	11,808=4·0721944	11,455=4·0662096	11,676=4·0678116	11,981=4·0787914	12,198=4·0862794	18,733=4·1877748	3,395 3·3303839 3·41 3·3375544	3,397 3·3310965 3·30 3·3185139	3,407 3·3323723 3·36 3·3263393	3,407 3·3323723 3·45 3·3781917	3,407 3·3323723 3·36 3·3263393	3,400 3·3314789 3·96 3·5970952	1·02	1·02	1·02	1·02	1·02	1·02	1·02	11,808=4·0721944	11,455=4·0662096	11,676=4·0678116	11,981=4·0787914	12,198=4·0862794	18,733=4·1877748	118,076=5·0721414 3·38853	8·4600714= 288 849 800
C.	1·00	28,405=4·4538917	28,094=4·4486124	27,784=4·4438623	29,760=4·4736282	28,706=4·4579763	29,171=4·4649484	6,500 8·8160938 4·33 8·8160938 1·00 ..	6,564 8·8171686 4·28 8·8144438 1·00 ..	6,584 8·8184898 4·22 8·8184898 1·00 ..	6,584 8·8184898 4·52 8·8551384 1·00 ..	6,584 8·8184898 4·36 8·8934865 1·00 ..	6,570 8·8177654 4·44 8·8473830 1·00 ..	1·00	1·00	1·00	1·00	1·00	1·00	1·00	28,405=4·4538917	28,094=4·4486124	27,784=4·4438623	29,760=4·4736282	28,706=4·4579763	29,171=4·4649484	118,499=5·0796850 3·38853	8·4636216= 289 827 800
D.	1·02	27,457=4·4386522	27,184=4·4384167	27,141=4·4386311	27,660=4·4418514	27,429=4·4382172	27,145=4·4337443	6,631·50 8·7506341 4·78 8·7506341 1·02 ..	6,634·50 8·7608554 4·73 8·7608554 1·02 ..	6,649·50 8·7520100 4·71 8·7520100 1·02 ..	6,649·50 8·7520100 4·80 8·7520100 1·02 ..	5,649·5 8·7520100 4·76 8·7520100 1·02 ..	5,689 8·7513021 4·72 8·7513021 1·02 ..	1·02	1·02	1·02	1·02	1·02	1·02	1·02	27,457=4·4386522	27,184=4·4384167	27,141=4·4386311	27,660=4·4418514	27,429=4·4382172	27,145=4·4337443	118,069=5·0796849 3·38853	8·4606361= 288 825 800
E.	1·04	27,200=4·4345797	25,871=4·4128262	27,232=4·4350784	28,192=4·4501770	26,140=4·4170869	23,908=4·3785848	6,154 8·7891575 4·25 8·7891575 1·04 ..	6,157·60 8·7894115 4·04 8·7863814 1·04 ..	6,175·60 8·7906792 4·24 8·7906792 1·04 ..	6,175·60 8·7906792 4·99 8·7906792 1·04 ..	6,175·60 8·7906792 4·07 8·7906792 1·04 ..	6,162 8·7897922 3·75 8·7717088 1·04 ..	1·04	1·04	1·04	1·04	1·04	1·04	1·04	27,200=4·4345797	25,871=4·4128262	27,232=4·4350784	28,192=4·4501770	26,140=4·4170869	23,908=4·3785848	118,075=5·0721414 3·38853	8·4607714= 288 849 800
F.	1·04	27,200=4·4345797	25,871=4·4128262	27,232=4·4350784	28,192=4·4501770	26,140=4·4170869	23,908=4·3785848	6,154 8·7891575 4·25 8·7891575 1·04 ..	6,157·60 8·7894115 4·04 8·7863814 1·04 ..	6,175·60 8·7906792 4·24 8·7906792 1·04 ..	6,175·60 8·7906792 4·99 8·7906792 1·04 ..	6,175·60 8·7906792 4·07 8·7906792 1·04 ..	6,162 8·7897922 3·75 8·7717088 1·04 ..	1·04	1·04	1·04	1·04	1·04	1·04	1·04	27,200=4·4345797	25,871=4·4128262	27,232=4·4350784	28,192=4·4501770	26,140=4·4170869	23,908=4·3785848	118,075=5·0721414 3·38853	8·4607714= 288 849 800

Figures marked a are corrected ones to true 1875 datum at 40' 0".

Appendix No. III.

Discharges of the Nawoon River at Thapangyo.

Month and year.	Date.	Gauge Reading.	Measured discharge.	Scaled discharge.	Difference.	Per cent.
August 1872.	1	37·10	191,953,000	193,472,400	+ 1,519,400	+ ·79
	2	36·80	186,935,000	184,133,200	− 2,801,800	− 1·48
	3	36·55	172,014,000	178,326,700	+ 6,312,700	+ 3·49
	4	36·45	161,222,000	176,004,100	+ 14,782,100	+ 8·69
	5	36·46	166,643,000	176,236,400	+ 9,593,400	+ 5·42
	6	36·72	193,294,000	182,275,200	− 11,018,800	− 5·70
	7	37·10	197,681,000	193,472,400	− 4,208,600	− 2·03
	8	37·46	200,963,000	204,379,600	+ 3,416,600	+ 1·49
	9	37·70	230,046,000	211,651,200	− 18,394,800	− 7·83
	10	37·39	229,931,000	217,407,800	− 12,523,200	− 5·22
	11	38·02	239,108,000	223,620,700	− 15,487,300	− 6·28
	12	38·12	249,495,000	227,537,500	− 21,957,500	− 8·83
	13	38·20	248,210,000	230,671,000	− 17,539,000	− 6·85
	14	38·30	254,750,000	234,587,800	− 20,162,200	− 7·87
	15	38·23	226,127,000	231,846,100	+ 5,719,100	+ 2·21
	16	38·15	220,456,000	228,712,600	+ 8,256,600	+ 3·64
	17	38·09	216,853,000	226,363,500	+ 9,510,500	+ 4·17
	18	37·96	217,107,000	219,528,600	+ 2,421,600	+ ·92
	19	37·82	209,310,000	215,286,900	+ 5,976.900	+ 2·40
	20	37·74	216,153,000	212,863,100	− 3,289,900	− 1·40
	21	37·74	225,549,000	212,863,100	− 12,685,900	− 5·33
	22	37·76	229,738,000	213,469,000	− 16,269,000	− 6·98
	23	37·83	226,164,000	215,589,900	− 10,574,100	− 4·42
	24	38·12	228,148,000	227,537,500	− 60,10,500	− ·26
	25	38·36	228,018,000	236,937,900	+ 8,919,900	+ 3·56
	26	38·47	229,530,000	241,246,500	+ 11,716,500	+ 4·80
	27	38·52	233,896,000	243,204,900	+ 9,308,900	+ 3·86
	28	38·54	226,394,000	243,988,300	+ 17,594,300	+ 7·52
	29	38·58	244,313,000	245,455,000	+ 1,142,000	+ ·41
	30	38·61	246,601,000	246,730,000	+ 129,000	+ ·05
	31	38·67	247,003,000	249,080,200	+ 2,077,200	+ ·81
		Total ...	6,793,605,000	6,744,479,100	− 49,125,900	
September 1872.	1	38·70	247,797,000	250,255,200	+ 2,458,200	+ ·82
	2	38·67	245,671,000	249,080,200	+ 3,409,200	+ 1·22
	3	38·62	246,682,000	247,121,700	+ 439,700	+ ·17
	4	38·54	234,349,000	243,988,300	+ 9,639,300	+ 3·85
	5	38·88	232,157,000	240,721,300	+ 8,564,300	+ 3·44
	6	38·20	223,791,000	230,671,000	+ 6,880,300	+ 2·70
	7	37·95	214,384,000	219,225,600	+ 4,841,600	+ 1·87
	8	37·70	212,471,000	211,651,200	− 819,800	− ·38
	9	37·50	205,484,000	205,591,600	+ 107,600	+ ·04
	10	37·33	192,224,000	200,440,900	+ 8,216,900	+ 4·16
	11	37·48	195,114,000	204,985,600	+ 9,871,600	+ 4·62
	12	37·55	194,568,000	207,106,500	+ 12,538,500	+ 6·18
	13	37·48	187,363,000	204,985,600	+ 17,622,600	+ 9·09
	14	37·42	189,374,000	203,167,700	+ 13,793,700	+ 7·41
	15	37·28	184,677,000	198,926,000	+ 14,249,000	+ 7·61
	16	37·08	188,489,000	192,866,400	+ 4,377,400	+ 2·13
	17	36·92	180,130,000	186,920,400	+ 6,790,400	+ 3·33
	18	36·82	179,134,000	184,597,800	+ 5,463,800	+ 2·80
	19	36·73	171,995,000	182,507,400	+ 10,512,400	+ 5·81
	20	36·44	164,675,000	175,771,900	+ 11,096,900	+ 6·71
	21	35·95	149,090,000	163,372,500	+ 14,282,500	+ 9·40
	22	35·31	138,300,000	152,050,000	+ 13,750,000	+ 9·48
	23	34·54	128,155,000	139,391,490	+ 11,236,490	+ 8·60
	24	33·68	122,790,000	128,103,700	+ 5,313,700	+ 4·09
	25	33·27	122,993,000	123,884,200	+ 891,200	+ ·65
	26	33·43	131,678,000	125,530,800	− 6,147,200	+ 4·60
	27	33·92	143,208,000	130,573,710	− 12,634,290	− 8·40
	28	34·45	153,889,000	138,180,700	− 15,708,300	− 9·80
	29	34·97	158,581,000	145,176,400	− 13,404,600	− 8·23
	30	35·49	172,719,000	155,322,500	− 17,396,500	− 9·87
		Total ...	5,511,932,000	5,642,168,300	+ 130,236,300	

Appendix No. III.—continued.

Discharges of the Nawoon River at Thapangyo.

Month and year.	Date.	Gauge Reading.	Measured discharge.	Scaled discharge.	Difference.	Per cent.
October 1872.	1	36·00	186,475,000	165,552,400	− 20,922,600	−11·30
	2	36·45	191,673,000	176,004,100	− 15,668,900	− 7·86
	3	36·80	200,625,000	184,133,200	− 16,491,800	− 8·00
	4	37·04	201,005,000	191,654,480	− 9,350,520	− 4·48
	5	37·23	201,668,000	197,411,100	− 4,256,900	− 1·99
	6	37·50	211,426,000	205,591,600	− 5,834,400	− 2·37
	7	37·70	212,185,000	211,651,200	− 533,800	− ·24
	8	37·36	209,014,000	201,349,800	− 7,664,200	− 3·35
	9	37·31	207,043,000	199,834,900	− 7,208,100	− 3·38
	10	37·28	205,861,000	198,926,000	− 6,935,000	− 2·92
	11	37·24	202,243,000	197,714,100	− 4,528,900	− 1·98
	12	37·18	196,816,000	195,896,200	− 919,800	− ·46
	13	36·96	194,920,000	188,849,400	− 6,070,600	− 3·08
	14	36·83	187,899,000	184,830,000	− 3,069,000	− 1·60
	15	36·62	187,359,000	179,952,600	− 7,406,400	− 3·74
	16	36·46	181,668,000	176,236,400	− 5,431,600	− 2·76
	17	36·39	181,490,000	174,610,600	− 6,879,400	− 3·86
	18	36·44	188,905,000	175,771,900	− 13,133,100	− 7·04
	19	36·64	196,482,000	180,417,100	− 16,064,900	− 8·16
	20	36·94	200,322,000	187,384,900	− 12,937,100	− 6·50
	21	37·11	204,821,000	193,775,400	− 11,055,600	− 5·38
	22	37·28	208,561,000	198,926,000	− 9,635,000	− 4·33
	23	37·41	212,564,000	202,864,700	− 9,699,300	− 4·26
	24	37·27	205,450,000	198,622,900	− 6,827,100	− 2·93
	25	37·04	192,626,000	191,654,480	− 971,520	− ·46
	26	36·64	176,257,000	180,417,100	+ 4,160,100	+ 2·28
	27	36·10	159,196,000	167,875,100	+ 8,679,100	+ 5·04
	28	35·38	146,378,000	153,288,400	+ 6,910,400	+ 4·79
	29	34·45	130,452,000	138,180,700	+ 7,728,700	+ 5·38
	30	33·30	118,436,000	124,192,900	+ 5,756,900	+ 4·27
	31	32·05	107,292,000	112,976,600	+ 5,684,600	+ 4·67
		Total ...	5,807,112,000	5,636,546,260	−170,565,740	
November 1872.	1	30·70	106,512,000	103,953,800	− 2,558,200	− 1·88
	2	29·70	103,959,000	98,635,800	− 5,323,200	− 4·81
	3	29·20	102,683,000	96,274,000	− 6,409,000	− 5·88
	4	30·16	111,294,000	101,054,200	− 10,239,800	− 9·01
	5	30·16	114,549,000	101,054,200	− 13,494,800	−11·40
	6	30·57	116,931,000	103,255,500	− 13,675,500	−11·12
	7	30·49	114,580,000	102,925,800	− 11,654,200	− 9·65
	8	30·10	108,722,000	100,730,900	− 7,991,100	− 7·40
	9	28·81	102,864,000	94,424,100	− 8,439,900	− 7·76
	10	27·70	94,607,700	89,603,700	− 5,004,000	− 5·32
	11	25·88	85,425,000	81,062,400	− 4,362,600	− 4·71
	12	24·83	78,138,500	77,766,500	− 372,000	− ·48
	13	23·60	73,142,900	72,735,700	− 407,200	− ·55
	14	22·50	66,958,400	68,236,600	+ 1,278,200	+ 1·49
	15	21·60	64,022,700	64,555,500	+ 532,800	+ ·78
	16	20·74	59,709,600	61,037,900	+ 1,328,300	+ 1·69
	17	20·05	56,798,400	58,215,800	+ 1,417,400	+ 1·78
	18	19·46	53,673,800	55,802,600	+ 2,037,800	+ 3·77
	19	18·91	52,673,800	53,553,000	+ 879,200	+ 1·56
	20	18·41	48,580,900	51,508,000	+ 2,927,100	+ 6·25
	21	17·99	48,010,900	49,790,100	+ 1,779,200	+ 2·08
	22	17·60	46,014,600	48,195,000	+ 2,180,400	+ 4·35
	23	17·21	45,383,200	46,579,900	+ 1,196,700	+ 2·23
	24	16·98	45,026,300	45,659,100	+ 632,800	+ 1·34
	25	16·55	43,005,500	43,900,300	+ 894,800	+ 1·81
	26	16·28	41,112,000	42,796,000	+ 1,684,000	+ 2·43
	27	15·96	38,854,000	41,467,100	+ 2,613,100	+ 5·28
	28	15·74	38,822,100	40,587,300	+ 1,765,200	+ 2·63
	29	15·49	38,462,500	39,564,800	+ 1,102,300	+ 2·61
	30	15·28	38,160,600	38,705,900	+ 545,300	+ 1·31
		Total ...	2,138,768,400	2,073,631,500	− 65,136,900	

Appendix No. III.—continued.

Discharges of the Nawoon River at Thapangyo.

Month and year.	Date.	Gauge Reading.	Measured discharge.	Scaled discharge.	Difference.	Per cent.
December 1872.	1	15·10	37,929,200	37,969,700	+ 40,500	+ ·10
	2	14·92	36,977,500	37,233,400	+ 255,900	+ ·55
	3	14·73	35,328,700	36,456,300	+ 1,127,600	+ 2·86
	4	14·59	34,927,400	35,883,700	+ 956,300	+ 2·59
	5	14·35	34,060,200	34,902,100	+ 841,900	+ 2·36
	6	14·20	33,518,300	34,288,600	+ 770,300	+ 2·09
	7	14·02	32,874,900	33,552,400	+ 677,500	+ 1·83
	8	13·84	32,231,500	32,816,100	+ 584,600	+ 1·56
	9	13·65	31,709,200	32,039,000	+ 329,800	+ ·95
	10	13·50	31,297,000	31,425,500	+ 128,500	+ ·32
	11	14·00	31,754,000	33,470,600	+ 1,716,600	+ 3·22
	12	13·28	31,120,800	30,525,700	− 595,100	− 1·93
	13	13·16	30,345,300	30,034,900	− 310,400	− ·99
	14	13·02	30,396,700	29,462,300	− 934,400	− 2·96
	15	12·95	29,794,900	29,175,900	− 619,000	− 2·01
	16	12·75	29,922,100	28,357,900	− 1,564,200	− 3·33
	17	12·57	27,507,500	27,621,700	+ 114,200	+ ·36
	18	12·41	27,005,900	26,967,300	− 38,600	− ·14
	19	12·18	24,784,600	26,026,600	+ 1,242,000	+ 4·10
	20	12·12	24,681,800	25,781,200	+ 1,099,400	+ 4·18
	21	12·00	24,476,200	25,290,360	+ 814,160	+ 3 28
	22	11·84	24,155,900	24,501,700	+ 345,800	+ 1·24
	23	11·69	24,031,100	23,947,700	+ 83,400	+ ·33
	24	11·43	24,380,800	22,986,500	− 1,394,300	− 5·17
	25	11·40	24,265,900	22,875,600	− 1,390,300	− 5·18
	26	11·21	24,148,500	22,173,200	− 1,975,300	− 8·33
	27	11·10	23,793,800	21,766,500	− 2,027,300	− 8·54
	28	10·96	22,714,900	21,119,400	− 1,595,500	− 6·35
	29	10·87	22,458,800	20,846,400	− 1,612,400	− 7·55
	30	10·75	22,232,900	20,482,300	− 1,750,600	− 7·85
	31	10·67	21,415,900	20,239,600	− 1,176,300	− 5·49
		Total...	886,242,200	880,220,160	− 6,022,040	
January 1873 by 1872 scale.	1	10·57	20,474,000	19,936,200	− 537,800	− 2·62
	2	10 48	19,957,800	19,663,100	− 294,700	− 1·50
	3	10·39	19,825,700	19,390,100	− 435,600	− 2·02
	4	10·30	19,740,100	19,117,000	− 623,100	− 3·04
	5	10·19	19,436,700	18,783,300	− 653,400	− 3·10
	6	10·07	19,253,300	18,419,200	− 834,100	− 4·16
	7	9·96	18,558,500	17,984,800	− 573,700	− 3·09
	8	9·85	18,345,600	17,708,200	− 637,400	− 3·28
	9	9·75	17,504,100	17,456,600	− 47,500	− ·28
	10	9·65	17,261,900	17,205,100	− 56,800	− ·33
	11	9·55	16,809,300	16,953,600	+ 144,300	+ ·86
	12	9·47	16,616,000	16,752,400	+ 136,400	+ ·60
	13	9·33	16,408,100	16,400,300	− 7,800	− 0·4
	14	9·26	15,862,500	16,224,200	+ 361,700	+ 1·90
	15	9·19	15,764,700	16,048,100	+ 283,400	+ 1·75
	16	9·10	15,532,300	15,821,800	+ 289,500	+ 1·86
	17	9·01	15,466,200	15,595,400	+ 129,200	+ ·83
	18	8·93	15,368,300	15,329,600	− 38,700	− ·25
	19	8·86	15,434,400	15,181,400	− 253,000	− 1·63
	20	8·80	15,096,500	15,054,300	− 42,200	− ·28
	21	8·80	15,899,200	15,054,300	− 844,900	− 5·32
	22	8·81	15,681,500	15,075,500	− 606,000	− 3·87
	23	8·79	15,750,000	15,033,100	− 716,900	− 4·55
	24	8·69	15,522,500	14,821,300	− 701,200	− 4·51
	25	8·59	15,546,900	14,609,500	− 937,400	− 6·03
	26	8·49	14,323,800	14,397,800	+ 74,000	+ ·52
	27	8·45	14,512,100	14,313,100	− 199,000	− 1·37
	28	8·45	15,794,000	14,313,100	− 1,480,900	− 9·37
	29	8·53	15,571,400	14,482,500	− 1,088,900	− 6·99
	30	8·58	15,368,300	14,588,400	− 779,900	− 5·07
	31	8·55	14,986,700	14,524,800	− 461,900	− 3·09
		Total ...	517,672,400	506,238,100	− 11,434,300	

Appendix No. III.—continued.

Discharges of the Nowoon River at Thapangyo.

Month and year.	Date.	Gauge Reading.	Measured discharge.	Scaled discharge.	Difference.	Per cent.
February 1873 by 1872 scale.	1	8·50	14,605,100	14,609,500	+ 4,400	+ ·03
	2	8·39	14,458,300	14,185,980	− 272,320	− 1·88
	3	8·29	14,348,200	13,974,200	− 374,000	− 2·61
	4	8·16	13,868,700	13,698,900	− 169,800	− 1·23
	5	8·01	13,506,700	13,381,200	− 125,500	− ·93
	6	7·91	13,567,800	13,127,700	− 440,100	− 3·24
	7	7·83	13,614,300	12,982,000	− 632,300	− 4·64
	8	7·72	12,882,800	12,781,700	− 101,100	− ·78
	9	7·63	12,599,000	12,617,700	+ 18,700	+ ·14
	10	7·56	12,334,800	12,490,200	+ 155,400	+ 1·26
	11					
	12					
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	17					
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	25					
	26					
	27					
	28					
				1873.		
July 1873.	1	33·40	144,421,000	131,750,420	− 12,670,580	− 8·78
	2	*a* 33·36	*a* 142,029,000	131,258,410	− 10,770,590	− 7·58
	3	*a* 33·30	*a* 139,637,000	130,520,400	− 9,116,600	− 6·53
	4	33·15	134,853,000	128,675,370	− 6,177,630	− 4·58
	5	*a* 33·06	*a* 130,055,200	127,568,350	− 2,486,850	− 1·91
	6	*a* 32·97	*a* 125,257,500	125,905,390	+ 647,890	+ ·52
	7	31·80	115,662,000	114,717,360	− 944,640	− ·81
	8	*a* 31·36	*a* 112,514,000	111,399,060	− 1,114,940	− ·99
	9	*a* 30·92	*a* 109,366,000	107,887,630	− 1,478,370	− 1·35
	10	30·05	103,070,000	102,492,070	− 577,930	− ·56
	11	*a* 29·83	*a* 99,498,200	101,084,770	+ 1,586,570	+ 1·59
	12	*a* 29·61	*a* 95,926,400	99,909,140	+ 3,982,740	+ 4·15
	13	29·17	88,782,800	97,557,870	+ 8,775,070	+ 9·88
	14	*a* 30·79	*a* 104,927,400	107,081,400	+ 2,154,000	+ 2·05
	15	*a* 31·61	*a* 112,999,700	113,284,580	+ 284,880	+ ·25
	16	*a* 32·43	*a* 117,035,800	120,766,530	+ 3,730,730	+ 3·19
	17	33·25	121,072,000	129,905,390	+ 8,833,390	+ 7·29
	18	34·54	130,915,000	152,696,180	+ 21,781,180	+ 16·63
	19	35·35	135,164,000	164,650,100	+ 29,486,100	+ 21·81
	20	*a* 35·51	*a* 146,306,500	168,025,780	+ 21,719,280	+ 14·84
	21	35·67	157,449,000	171,400,460	+ 13,951,460	+ 8·86
	22	35·75	168,755,000	173,089,300	+ 5,334,300	+ 3·17
	23	35·73	165,243,000	172,667,340	+ 7,424,340	+ 4·49
	24	35·77	170,539,000	173,511,260	+ 2,972,260	+ 1·80
	25	35·63	166,867,000	170,557,540	+ 3,690,540	+ 2·21
	26	35·37	159,823,000	165,072,060	+ 5,249,060	+ 3·28
	27	*a* 35·03	*a* 150,236,000	157,898,740	+ 7,662,740	+ 5·10
	28	34·70	140,649,000	151,270,360	+ 10,621,360	+ 7·55
	29	35·01	140,886,000	157,476,780	+ 16,590,780	+ 11·78
	30	35·27	141,131,000	162,962,260	+ 21,831,260	+ 15·47
	31	35·33	151,589,000	164,228,140	+ 13,639,140	+ 9·05
		Total ...	4,121,659,500	4,287,270,440	+ 165,610,940	

N. B.—Figures marked *a* are interpolated ones.

Appendix No. III.—continued.

Discharges of the Nawoon River at Thapangyo.

Month and year.	Date.	Gauge Reading.	Measured discharge.	Scaled discharge.	Difference.	Per cent.
August 1873.	1	*a* 35·02	*a* 149,099,000	157,687,760	+ 8,588,760	+ 5·37
	2	34·72	147,609,000	151,592,130	+ 3,983,130	+ 2·70
	3	*a* 34·89	*a* 161,556,000	154 327,190	− 7,228,810	− 4·34
	4	35·07	175,503,000	158,742,660	− 16,760,340	− 9·54
	5	35·61	185,890,000	170,135,580	− 15,754,420	− 8·47
	6	36·12	200,716,000	183,189,720	− 17,526,280	− 8·51
	7	36·53	213,332,000	194,491,780	− 18,840,220	− 8·83
	8	36·82	224,275,000	202,485,920	− 21,789,080	− 9·72
	9	36·99	226,283,000	207,172,140	− 19,110,860	− 8·40
	10	*a* 37·08	*a* 231,871,000	212,238,410	− 19,632,590	− 8·22
	11	37·18	237,459,000	215,813,550	− 21,645,450	− 8·86
	12	37·18	232,772,000	215,813,550	− 16,958,450	− 7·28
	13	37·11	225,099,000	213,310,950	− 11,788,050	− 5·23
	14	36·94	218,169,000	205,803,840	− 12,365,160	− 5·50
	15	36·72	208,256,000	199,729,320	− 8,526,680	− 3·84
	16	36·50	200,929,000	193,664,800	− 7,264,200	− 3·48
	17	*a* 36·20	*a* 192,396,500	185,395,000	− 7,001,500	− 3·54
	18	35·90	183,864,000	176,254,000	− 7,610,000	− 3·82
	19	35·54	173,977,000	168,658,720	− 5,318,280	− 2·87
	20	35·17	168,379,000	160,852,460	− 7,526,540	− 4·17
	21	34·94	165,666,000	155,131,840	− 10,534,160	− 6·96
	22	34·71	162,226,000	151,431,250	− 10,794,750	− 6·69
	23	34·62	161,610,000	149,983,270	− 11,626,730	− 6·85
	24	*a* 34·81	*a* 170,652,500	153,040,100	− 17,612,400	− 10·02
	25	35·00	179,695,000	157,265,800	− 22,429,200	− 12·30
	26	35·34	190,796,000	164,439,120	− 26,356,880	− 13·81
	27	35·63	195,344,000	170,557,540	− 24,786,460	− 12·69
	28	35·92	199,402,000	176,675,900	− 22,726,100	− 11·42
	29	36·20	203,877,000	185,395,000	− 18,482,000	− 8·82
	30	36·44	211,913,000	192,010,840	− 19,902,160	− 9·39
	31	*a* 36·51	*a* 211,115,500	193,940,500	− 17,175,000	− 8·06
		Total ...	6,009,731,500	5,577,230,640	− 432,500,860	
September 1873.	1	36·66	210,318,000	198,075,360	− 12,242,640	− 5·71
	2	36·60	208,219,000	196,421,400	− 11,797,600	− 5·67
	3	36·53	207,818,000	194,491,780	− 13,326,220	− 6·28
	4	36·37	194,395,000	190,081,220	− 4,313,780	− 2·06
	5	36·12	179,297,000	183,189,720	+ 3,892,720	+ 2·18
	6	35·84	160,345,000	174,988,620	+ 14,643,620	+ 8·75
	7	35·20	153,516,500	161,485,400	+ 7,968,900	+ 5·16
	8	34·57	146,678,000	149,178,840	+ 2,500,840	+ 1·37
	9	33·97	144,431,000	138,761,530	+ 5,669,470	− 3·47
	10	33·72	130,008,000	135,686,480	+ 5,678,480	+ 4·36

N. B.—Figures marked *a* are interpolated ones.

Appendix No. III.—continued.

Discharge Scales of the Nawoon River at Thapangyo for the years 1872 *&* 1873.

1872 Scale.			1873 Scale.		
Gauge Reading.	Discharge in Cubic Metre Tons.	Difference of Discharge.	Discharge in Cubic Metre Tons.	Difference of Discharge.	Gauge Reading.
·5	7,620,180	.....			
5.	8,322,080	701,900			
·5	9,051,280	729,200			
6·	9,814,080	762,800			
·5	10,617,680	803,600			
7·	11,470,240	852,560			
·5	12,380,940	910,700			
8·	13,360,040	979,100			
·5	14,418,940	1,058,900			
9·	15,570,240	1,151,300			
·5	16,827,800	1,257,560			
10·	18,206,800	1,379,000			
·5	19,723,800	1,517,000			
11·	21,396,800	1,673,000			
·5	23,245,300	1,848,500			
12·	25,290,360	2,045,060			
·5	27,335,420	2,045,060			
13·	29,380,480	2,045,060			
·5	31,425,540	2,045,060			
14·	33,470,600	2,045,060			
·5	35,515,660	2,045,060			
15·	37,560,720	2,045,060			
·5	39,605,780	2,045,060			
16·	41,650,840	2,045,060			
·5	43,695,900	2,045,060			
17·	45,740,960	2,045,060			
·5	47,786,020	2,045,060			
18·	49,831,080	2,045,060			
·5	51,876,140	2,045,060			
19·	53,921,200	2,045,060			
·5	55,966,260	2,045,060			
20·	58,011,320	2,045,060			
·5	60,056,380	2,045,060			
21·	62,101,440	2,045,060			
·5	64,146,500	2,045,060			
22·	66,191,560	2,045,060			
·5	68,236,620	2,045,060			
23·	70,281,680	2,045,060			
·5	72,326,740	2,045,060			
24·	74,371,800	2,045,060			
·5	76,416,860	2,045,060	76,000,000	.....	·5
25·	78,461,920	2,045,060	78,200,660	2,200,660	25·
·5	80,507,620	2,045,700	80,403,960	2,203,300	·5
26·	82,555,880	2,048,260	82,613,860	2,209,900	26·
·5	84,610,540	2,054,660	84,836,960	2,223,100	·5
27·	86,678,000	2,067,460	87,083,160	2,246,200	27·
·5	88,767,860	2,089,860	89,366,320	2,283,160	·5
28·	90,893,560	2,125,700	91,704,920	2,338,600	28·
·5	93,073,020	2,179,460	94,122,720	2,417,800	·5
29·	95,329,280	2,256,260	96,649,420	2,526,700	29·
·5	97,691,140	2,361,860	99,321,320	2,671,900	·5
30·	100,193,800	2,502,660	102,181,980	2,860,660	30·
·5	102,879,500	2,685,700	105,282,880	3,100,900	·5
31·	105,798,160	2,918,660	108,684,080	3,401,200	31·
·5	109,008,020	3,209,860	112,454,880	3,770,800	·5
32·	112,576,280	3,568,260	116,674,480	4,219,600	32·
·5	116,579,740	4,003,460	121,432,640	4,758,160	·5
33·	121,105,440	4,525,700	126,830,340	5,397,700	33·
·5	126,251,300	5,145,860	132,980,440	6,150,100	·5
34·	132,126,760	5,875,460	140,008,340	7,027,900	34·
·5	138,853,420	6,726,660	148,052,640	8,044,300	·5
35·	146,565,680	7,712,260	157,265,800	9,213,160	35·
·5	155,411,380	8,845,700	167,814,800	10,549,000	·5
36·	165,552,440	10,141,060	179,881,800	12,067,000	36·
·5	177,165,500	11,613,060	193,664,800	13,783,000	·5
37·	190,442,560	13,277,060	209,378,300	15,713,500	37·
·5	205,591,620	15,149,060	227,253,960	17,875,660	·5
38·	222,837,320	17,245,700	247,541,260	20,287,300	38·
5·	242,421,580	19,584,260	270,508,160	22,966,900	·5
39·	264,604,240	22,182,660	296,441,760	25,933,600	39·
5·	289,663,700	25,050,460	325,648,960	29,207,200	·5
40·	317,897,560	28,233,860	358,457,120	32,808,160	40·
·5	349,623,260	31,725,700	395,214,720	36,757,600	·5

Appendix No. III.—continued.

Discharges of the Nawoon River at Thapangyo.

	Year.	Date.	Gauge Reading.	Measured discharge C. Metre (tons) per day.	Scaled discharge C. Metre (tons) per day.	Difference.	Per cent.
		1					
		2					
		3					
		4					
		5					
		6					
		7					
		8					
		9					
		10					
		11					
		12					
		13					
		14					
		15					
		16					
		17	38·42	297,093,000	277,811,752	— 19,281,248	— 6·48
		18	38·29	285,163,500	272,091,154	— 13,072,346	— 4·58
		19	38·23	279,657,000	269,450,878	— 10,206,122	— 3·64
		20	38·09	278,228,000	263,290,234	— 14,937,766	— 5·37
		21	38·05	277,719,000	261,530,050	— 16,188,950	— 5·83
		22	38·05	277,179,000	261,530,050	— 15,648,950	— 5·64
		23	38·00	263,051,000	259,329,820	— 3,721,180	— 1·14
		24	37·92	254,872,000	254,309,844	— 562,156	— ·19
		25	37·84	253,955,000	251,554,388	— 2,400,612	— ·94
		26	37·92	253,038,000	254,309,844	+ 1,271,844	+ ·50
		27	37·92	256,727,000	254,309,844	— 2,417,156	— ·94
		28	37·85	247,232,000	251,898,820	+ 4,666,820	+ ·88
		29	37·70	241,659,000	236,732,340	— 4,926,660	— 2·68
		30	37·33	224,343,500	233,988,356	+ 9,644,856	+ 4·12
	July 1875.	31	37·25	220,057,400	231,232,900	+ 11,175,500	+ 4·83
		1	37·33	227,765,900	233,988,356	+ 6,222,456	+ 2·73
		2	37·40	234,511,000	229,510,740	— 5,000,260	— 2·13
		3	37·80	250,633,000	250,176,660	— 456,340	— ·18
		4	37·80	260,917,000	250,176,660	— 10,740,340	— 4·11
		5	37·98	268,349,000	256,376,436	— 11,972,564	— 4·47
		6	38·05	272,430,300	261,530,050	— 10,900,250	— 4·03
		7	38·10	286,137,500	263,730,280	— 22,407,220	— 7·69
		8	38·15	288,372,200	265,930,510	— 22,441,690	— 7·63
		9	38·20	290,607,000	268,130,740	— 22,476,260	— 7·58
		10	38·25	291,438,700	270,330,970	— 21,107,730	— 7·21
		11	38·40	293,934,000	276,931,660	— 17,002,340	— 5·78
		12	39·00	306,530,800	306,120,260	— 410,540	— ·13
		13	38·67	303,627,000	288,812,902	— 14,814,098	— 4·93
		14	38·93	317,618,400	300,254,098	— 17,364,302	— 5·34
		15	39·10	326,766,700	311,692,680	— 15,074,020	— 4·58
		16	39·27	335,915,000	321,165,794	— 14,749,206	— 4·46
		17	39·55	343,154,300	336,768,570	— 6,385,730	— 1·77
		18	39·75	348,325,300	347,913,410	— 411,190	— ·11
		19	39·88	356,540,624	355,157,556	— 1,383,068	— ·38
		20	40·00	364,124,000	365,225,940	+ 1,101,940	+ ·30
		21	39·94	358,260,300	358,501,008	+ 240,708	+ ·07
		22	39·77	347,347,100	349,027,894	+ 1,680,794	+ ·48
		23	39·60	336,434,000	339,554,780	+ 3,120,780	+ ·92
		24	39·37	327,890,500	326,738,214	— 1,152,286	— ·35
		25	39·15	318,809,500	314,478,890	— 4,330,610	— 1·35
		26	38·92	302,746,000	299,814,052	— 2,931,948	— ·96
		27	38·67	289,320,300	288,812,902	— 507,398	— ·17
		28	38·42	270,876,800	277,811,752	+ 6,934,952	+ 2·58
		29	38·24	262,639,800	269,890,924	+ 7,251,124	+ 2·66
		30	38·05	262,639,800	261,530,050	— 1,109,750	— ·42
		31	38·00	258,992,000	259,329,820	+ 337,820	+ ·13
			Total ...	9,303,653,824	9,105,414,558	— 198,239,266	

Appendix No. III.—continued.

Discharges of the Nawoon River at Thapangyo.

Year.	Date.	Gauge Reading.	Measured discharge C. Metre (tons) per day.	Scaled discharge C. Metre (tons) per day.	Difference.	Per cent.
September 1875.	1	38·06	262,260,400	261,970,096	— 290,304	— ·11
	2	38·15	267,163,000	265,930,510	— 1,232,490	— ·46
	3	38·27	271,030,900	271,211,062	+ 180,162	+ ·06
	4	38·45	285,912,500	279,131,890	— 6,780,610	— 2·37
	5	38·56	289,865,800	283,972.396	— 5,893,404	— 2·03
	6	38·67	293,819,200	288,812,902	— 5,206,298	— 1·70
	7	38·78	294,404,000	291,453,178	— 2,950,822	— 1·00
	8	38·79	294,472,100	294,093,454	— 378,646	— ·12
	9	38.90	294,597,000	298,933,960	+ 4,336,960	+ 1·47
	10	38·92	297,960,200	299,814,052	+ 1,853,852	+ ·61
	11	38·95	303,005,000	301,134,190	— 1,870,810	— ·62
	12	38·98	308,049,800	302,454,328	— 5,595,472	— 1·94
	13	39·00	311,413,000	306,120,260	— 5,292,740	— 1·60
	14	38·92	297,960,200	299,814,052	+ 1,853,852	— ·67
	15	38·82	281,144,000	295,413,592	+14,269,592	+ 4·97
	16	38·58	266,531,700	284,852,488	+18,320,788	+ 6·76
	17	38·33	251,310,400	273,851,338	+22,540,938	+ 9·16
	18	38·02	240,925,000	260,209,912	+19,284,912	+ 7·88
	19	37·53	217,537,700	240,876,996	+23,339,296	+ 10·59
	20	37·03	193,673,000	223,655,396	+29,982,396	+ 15·46
	21	36·33	179,100,000	202,881,740	+23,781,740	+ 13·40
	22	36·40	180,179,200	204,754,800	+24,575,600	+ 13·88
	23	34·70	153,970,000	166,048,520	+12,078,520	+ 7·79
	24	33·65	133,285,600	149,690,290	+16,404,690	+ 12·03
	25	32·45	121,254,000	135,622,150	+14,368,150	+ 11·57
	26	31·29	114,495,800	125,142,408	+10,646,608	+ 9·64
	27	30·13	107,737,600	116,731,898	+ 8,994,298	+ 8·33
	28	28·90	102,394,700	109,154,720	+ 6,760,020	+ 6·92
	29	27·97	97,978,900	104,182,758	+ 6,203,858	+ 6·12
	30	27·35	94,563,700	100,882,790	+ 6,319,090	+ 6·31
		Total ...	6,807,994,400	7,038,798,126	+ 230,803,726	
October 1875.	1	26·81	92,212,700	98,098,174	+ 5,885,474	+ 6·52
	2	26·50	93,509,300	96,534,720	+ 3,025,420	+ 3·32
	3	26·47	92,510,300	96,383,418	+ 3,873,118	+ 4·34
	4	26·43	95,830,500	96,181,682	+ 351,182	+ ·36
	5	27·75	108,640,000	102,945,270	— 5,694,730	— 5·50
	6	28·48	109,665,400	106,882,856	— 2,782,544	— 2·72
	7	28·40	106,319,000	106,450,120	+ 131,120	+ ·09
	8	28·63	109,340,000	107,694,236	— 1,645,764	— 1·83
	9	28·85	107,195,000	108,984,260	+ 1,689,260	+ 1·86
	10	28·73	101,150,400	108,235,156	+ 7,084,756	+ 7·92
	11	28·67	95,570,800	107,910,604	+12,339,804	+ 12·63
	12	28·60	113,239,600	107,531,960	— 5,707,640	— 5·03
	13	28·65	111,376,000	107,802,420	— 3,573,580	— 3·20
	14	28·86	110,847,000	108,938,352	— 1,908,648	— 1·80
	15	28·93	115,152,800	109,316,996	— 5,835,804	— 5·21
	16	28·64	110,078,900	107,748,328	— 2,330,572	— ·81
	17	28·40	108,494,900	106,882,856	— 1,612,044	— 1·85
	18	28·15	113,313,000	105,097,820	— 8,215,180	— 7·08
	19	28·75	118,939,800	108,343,340	—10,596,460	— 9·24
	20	29·28	121,890,200	111,446,188	—10,444,012	— 8·19
	21	29·17	120,048,000	110,798,662	— 9,249,338	— 7· 5
	22	28·80	114,566,000	108,613,800	— 5,952,200	— 5·21
	23	28·62	114,937,000	107,640,144	— 7,296,856	— 6·08
	24	28·62	113,881,500	107,640,144	— 6,241,356	— 5·26
	25	28·62	112,826,000	107,640,144	— 5,185,856	— 4·42
	26	28·40	112,841,000	106,450,120	— 6,390,880	— 5·30
	27	28·02	109,007,500	104,394,624	— 4,612,876	— 4·58
	28	27·45	105,455,000	101,398,410	— 4,056,590	— 3·80
	29	26·50	100,821,700	96,534,720	— 4,286,980	— 3·96
	30	25·55	97,347,700	91,754,030	— 5,593,670	— 6·18
	31	24·58	96,132,800	86,900,000	— 9,232,800	— 9·37
		Total ...	3,333,139,800	3,239,073,554	—94,066,246	

Appendix No. III.—continued.

Discharges of the Nawoon River at Thapangyo.

	Year.	Dated.	Gauge Reading.	Measured discharg C. Metre (tons) per day.	Scaled discharge C. Metre (tons) per day.	Difference.	Per cent.
	November 1875.	1	23·60	84,905,300	82,000,000	— 2,905,300	— 3·52
		2	22·82	79,175,800	78,100,000	— 1,075,800	— 1·26
		3	22·14	74,825,100	74,700,000	— 125,100	— ·16
		4	21·45	70,410,300	71,250,000	+ 839,700	+ 1·19
		5	20·85	67,009,700	68,250,000	+ 1,240,300	+ 1·49
		6	20·26	65,742,500	65,300,000	— 442,500	— ·67
		7	19·13	60,595,200	59,650,000	— 945,200	— 1·48
		8	18·57	58,021,550	56,850,000	— 1,171,550	— 1·72
		9	18·29	56,734,675	55,450,000	— 1,284,675	— 1·75
		10	18·00	55,447,900	54,000,000	— 1,447,900	— 1·81
		11	17·53	51,844,400	51,650,000	— 194,400	— ·38
		12	17·14	49,265,900	49,700,000	+ 434,100	+ ·81
		13	16·77	48,329,000	47,850,000	— 479,000	— 1·03
		14	16·42	46,590,800	46,100,000	— 490,800	— 1·07
		15	16·07	44,852,600	44,350,000	— 502,600	— 1·11
		16	15·75	43,898,500	42,750,000	— 1,148,500	— 2·27

Appendix III.—continued.

Discharge Scale for the year 1875 *of the Nawoon River at Thapangyo.*

Gauge Reading.	Discharge in metre tons.	1st Difference.	2nd Difference.	3rd Difference.	4th Difference.	5th Difference.
15	39,000,000	2,500,000				
15·5	41,500,000	2,500,000				
16	44,000,000	2,500,000				
16·5	46,500,000	2,500,000				
17	49,000,000	2,500,000				
17·5	51,500,000	2,500,000				
18	54,000,000	2,500,000				
18·5	56,500,000	2,500,000				
19	59,000,000	2,500,000				
19·5	61,500,000	2,500,000				
20	64,000,000	2,500,000				
20·5	66,500,000	2,500,000				
21	69,000,000	2,500,000				
21·5	71,500,000	2,500,000				
22	74,000,000	2,500,000				
22·5	76,500,000	2,500,000				
23	79,000,000	2,500,000				
23·5	81,500,000	2,500,000				
24	84,000,000	2,500,000				
24·5	86,500,000	2,500,000				
25	89,000,620	2,500,620	620	620	620	620
25·5	91,503,720	2,503,100	2,480	1,860	1,240	...
26	94,013,020	2,509,300	6,200	3,720	1,860	...
26·5	96,534,720	2,521,700	12,400	6,200	2,480	...
27	99,078,120	2,543,400	21,700	9,300	3,100	...
27·5	101,656,240	2,578,120	34,720	13,020	3,720	...
28	104,286,440	2,630,200	52,080	17,360	4,340	...
28·5	106,991,040	2,704,600	74,400	22,320	4,960	...
29	109,797,940	2,806,900	102,300	27,900	5,580	...
29·5	112,741,240	2,943,300	136,400	34,100	6,200	...
30	115,861,860	3,120,620	177,320	40,920	6,820	...
30·5	119,208,160	3,346,300	225,680	48,360	7,440	...
31	122,836,560	3,628,400	282,100	56,420	8,060	...
31·5	126,812,160	3,975,600	347,200	65,100	8,680	...
32	131,209,360	4,397,200	421,600	74,400	9,300	...
32·5	136,112,480	4,903,120	505,920	84,320	9,920	...
33	141,616,380	5,503,900	600,780	94,860	10,540	...
33·5	147,827,080	6,210,700	706,800	106,020	11,160	...
34	154,862,380	7,035,300	824,600	117,800	11,780	...
34·5	162,852,480	7,990,100	954,800	130,200	12,400	...
35	171,940,600	9,088,120	1,098,020	143,220	13,020	...
35·5	182,283,600	10,343,000	1,254,880	156,860	13,640	...
36	194,051,600	11,768,000	1,425,000	171,120	14,260	...
36·5	207,430,600	13,379,000	1,611,000	186,000	14,880	...
37	222,622,100	15,191,500	1,812,500	201,500	15,500	...
37·5	239,843,720	17,221,620	2,030,120	217,620	16,120	...
38	259,329,820	19,486,100	2,264,480	234,360	16,740	...
38·5	281,332,120	22,002,300	2,516,200	251,720	17,360	...
39	306,120,260	24,788,140	2,785,840	269,640	17,920	...
39·5	333,982,420	27,862,160	3,074,020	288,180	18,540	...
40	365,225,940	31,243,520	3,381,360	307,340	19,160	...

Appendix No. III.—continued.

Discharges of the Nawoon River at Thapangyo.

Year.	Dated.	Gauge Reading.	Measured discharge C. Metre (tons) per day.	Scaled discharge C. Metre (tons) per day.	Difference.	Per cent
June 1878.	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					
	11					
	12					
	13					
	14					
	15					
	16					
	17	13·66	39,538,950	33,960,000	— 5,578,950	— 14·36
	18	14·27	41,153,580	37,620,000	— 3,533,580	— 8·58
	19	14·70	41,733,390	40,200,000	— 1,533,390	— ·36
	20	14·65	41,063,060	39,900,000	— 1,163,060	— 2·83
	21	14·80	45,192,600	40,800,000	— 4,392,600	— 8·88
	22	14·75	41,131,560	40,500,000	— 631,560	— 1·46
	23	14·61	40,764,600	39,660,000	— 1,104,600	— 2·43
	24	14·48	40,397,640	38,880,000	— 1,517,640	— 3·75
	25	14·75	45,028,700	40,500,000	— 4,528,700	— 10·05
	26	15·90	51,726,980	47,400,000	— 4,326,980	— 7·68
	27	18·15	60,313,900	60,900,000	+ 586,100	+ ·99
	28	20·08	71,606,530	72,480,000	+ 873,470	+ 1·25
	29	21·30	79,153,720	79,800,000	+ 646,280	+ ·79
	30	22·55	86,760,750	87,300,000	+ 539,250	+ ·57
July 1878.	1	23·81	94,367,780	94,860,000	+ 492,220	+ ·52
	2	25·08	103,275,400	102,491,700	— 783,700	— ·77
	3	26·25	108,151,100	109,594,500	+ 1,443,400	+ 1·33
	4	27·30	118,032,100	116,130,000	— 1,902,100	— 1·69
	5	28·12	119,563,300	121,449,300	+ 1,886,000	+ 1·66
	6	28·70	125,236,400	125,344,000	+ 107,600	+ ·08
	7	24·78	134,688,350	133,246,200	— 1,442,150	— 1·07
	8	30·87	144,140,300	142,384,000	— 1,756,300	— 1·21
	9	31·50	156,401,700	148,752,000	— 7,649,700	— 5·12
	10	31·95	158,398,000	153,196,200	— 5,201,800	— 3·16
	11	32·50	160,854,200	160,167,000	— 687,200	— ·43
	12	33·05	168,949,390	167,567,250	— 1,382,140	— ·81
	13	33·60	178,348,500	176,737,500	— 1,611,000	— ·90
	14	33·67	183,781,000	176,777,350	— 7,003,650	— 3·82
	15	33·73	188,437,480	177,668,650	—10,768,830	— 5·85
	16	34·03	190,233,220	183,124,500	— 7,108,720	— 3·68
	17	34·33	199,771,740	188,719,500	—11,052,240	— 5·52
	18	34·38	206,783,200	189,652,000	—17,131,200	— 8·21
	19	35·29	208,519,870	209,194,500	+ 674,630	+ ·33
	20	35·46	217,268,500	213,198,000	— 4,070,500	— 1·84
	21	35·68	221,574,100	218,378,800	— 3,195,300	— 1·35
	22	35·89	208,852,870	223,324,500	+14,471,630	+ 6·69
	23	36·03	208,322,000	236,270,030	+27,948,030	+ 13·46
	24	36·13	205,092,700	231,245.130	+26,152,430	+ 12·68
	25	36·23	225,674,400	234,200,230	+ 8,525,830	+ 3·77
	26	36·33	221,023,720	237,195,330	+16,171,610	+ 7·23
	27	36·53	216,573,700	243,145,530	+26,571,830	+ 12·03
	28	36·70	231,431,200	248,203,200	+16,772,000	+ 6·92
	29	36·88	247,162,680	253,558,380	+ 6,395,700	+ 2·42
	30	37·03	247,455,500	260,079,450	+12,623,950	+ 4·85
	31	37·10	250,366,300	262,702,000	+12,335,700	+ 4· 8
		Total ...	5,648,730,700	5,738,556,730	+89,826,030	

Appendix No. III.—continued.

Discharges of the Nawoon River at Thapangyo.

Year.	Date.	Gauge Reading.	Measured discharge C. Metre (tons) per day.	Scaled discharge C. Metre (tons) per day.	Difference.	Per cent.
August 1878.	1	37·23	263,210,400	267,572,450	+ 4,362,050	+ 1·52
	2	37·43	277,327,400	275,065,450	— 2,261,950	— ·77
	3	37·58	281,730,300	280,676,200	— 1,054,100	— ·35
	4	37·66	286,075,600	283,682,400	— 2,393,200	— 8·03
	5	37·73	289,877,800	286,304,950	— 3,572,850	— 1·04
	6	37·80	288,825,800	288,927,500	+ 101,700	+ ·03
	7	37·80	299,494,800	288,927,500	—10,567,300	— 3·34
	8	37·80	287,406,400	288,927,500	+ 1,521,100	+ ·34
	9	37·70	285,080,800	285,181,000	+ 100,200	+ ·03
	10	37·68	288,849,300	284,431,700	— 4,417,600	— 1·38
	11	37·63	284,543,350	282,558,450	— 1,984,900	— ·69
	12	37·58	280,237,400	280,676,200	+ 438,800	+ ·14
	13	37·60	281,900,600	281,434,500	— 466,100	— ·14
	14	37·63	284,395,600	282,558,450	— 1,837,150	— ·64
	15	37·48	285,374,200	276,938,700	— 8,435,500	— 2·80
	16	37·38	275,123,760	272,892,200	— 2,231,560	— ·72
	17	37·35	288,897,100	271,768,250	—17,128,850	— 5·90
	18	37·40	288,963,800	273,941,500	—15,022,300	— 5·20
	19	37·46	289,043,860	276,189,400	—12,854,460	— 4·49
	20	37·61	297,143,400	281,809,150	—15,334,250	— 5·05
	21	37·59	283,051,100	281,059,850	— 1,991,250	— ·70
	22	37·46	266,367,100	276,189,400	+ 9,822,300	+ 3·76
	23	37·28	256,141,500	267,572,450	+11,430,950	+ 4·29
	24	37·07	254,080,300	261,578,050	+ 7,497,750	+ 2·75
	25	36·91	252,019,300	254,450,910	+ 2,431,610	+ ·78
	26	36·58	247,897,060	244,633,080	— 3,263,980	— 1·21
	27	36·48	246,599,500	241,657,980	— 4,941,520	— 2·02
	28	36·33	238,412,900	237,195,330	— 1,217,570	— ·42
	29	36·16	236,316,300	232,137,600	— 4,178,700	— 1·69
	30	35·95	220,766,860	224,737,500	+ 3,970,640	+ 1·36
	31	35·73	221,429,860	219,556,500	— 1,873,360	— ·45
		Total ...	8,426,583,450	8,351,232,100	—75,351,350	

Appendix No. III.—concluded.

Discharge scale for the year 1878 *of the Nawoon River ot Thapangyo.*

Gauge Reading.	Discharge in Metre Tons.	1st Difference.	2nd Difference.	3rd Difference.	4th Difference.	5th Difference.
13	30,000,000	3,000,000				
13·5	33,000,000	3,000,000				
14	36,000,000	3,000,000				
14·5	39,000,000	3,000,000				
15	42,000,000	3,000,000				
15·5	45,000,000	3,000,000				
16	48,000,000	3,000,000				
16·5	51,000,000	3,000,000				
17	54,000,000	3,000,000				
17·5	57,000,000	3,000,000				
18	60,000,000	3,000,000				
18·5	63,000,000	3,000,000				
19	66,000,000	3,000,000				
19·5	69,000,000	3,000,000				
20	72,000,000	3,000,000				
20·5	75,000,000	3,000,000				
21	78,000,000	3,000,000				
21·5	81,000,000	3,000,000				
22	84,000,000	3,000,000				
22·5	87,000,000	3,000,000				
23	90,000,000	3,000,000	0			
23·5	93,000,000	3,000,000	0	0	0	0
24	96,000,500	3,000,500	500	500	500	500
24·5	99,003,000	3,002,500	2,000	1,500	1,000	,,
25	102,010,500	3,007,500	5,000	3,000	1,500	,,
25·5	105,028,000	3,017,500	10,200	5,200	2,000	,,
26	108,063,000	3,035,000	17,900	7,700	2,500	,,
26·5	111,126,000	3,063,000	28,600	10,700	3,000	,,
27	114,231,000	3,105,000	42,800	14,200	3,500	,,
27·5	117,396,000	3,165,000	61,000	18,200	4,000	,,
28	120,643,500	3,247,500	83,700	22,700	4,500	,,
28·5	124,001,000	3,357,500	111,400	27,700	5,000	,,
29	127,501,500	3,500,500	144,600	33,200	5,500	,,
29·5	131,184,000	3,682,500	183,800	39,200	6,000	,,
30	135,094,000	3,910,000	229,500	45,700	6,500	,,
30·5	139,284,000	4,190,000	282,200	52,700	7,000	,,
31	143,814,000	4,530,000	342,400	60,200	7,500	,,
31·5	148,752,000	4,938,000	410,600	68,200	8,000	,,
32	154,174,500	5,422,500	487,300	76,700	8,500	,,
32·5	160,167,000	5,992,500	573,000	85,700	9,000	,,
33	166,824,500	6,657,500	668,200	95,200	9,500	,,
33·5	174,252,000	7,427,500	773,400	105,200	10,000	,,
34	182,565,000	8,313,000	889,100	115,700	10,500	,,
34·5	191,890,000	9,325,000	1,015,800	126,700	11,000	,,
35	202,365,000	10,475,000	1,154,000	138,200	11,500	,,
35·5	214,140,000	11,775,000	1,304,200	150,200	12,000	,,
36	227,377,500	13,237,500	1,466,900	162,700	12,500	,,
36·5	242,253,000	14,875,500	1,642,600	175,700	13,000	,,
37	258,955,500	16,702,500	1,831,800	189,200	13,500	,,
37·5	277,688,000	18,732,500	2,035,000	203,200	14,000	,,
38	298,668,000	20,980,000	2,252,700	217,700	14,500	,,
38·5	322,128,000	23,460,000	2,485,400	232,700	15,000	,,
39	348,316,000	26,188,000	2,733,600	248,200	15,500	,,
39·5	377,496,000	29,180,000	2,997,800	264,200	16,000	,,
40	409,948,500	32,452,500	3,278,500	280,700	16,500	,,

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on 24 February, 2020